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ANIMAL COLOR CHANGES AND THEIR NEUROHUMORS

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I. HISTORICAL INTRODUCTION

THE modern intensive investigation of the color changes in animals may be said to have begun with the publication in 1852 of Brücke's elaborate monograph on the African chameleon. According to this worker the severance of a cutaneous nerve in the chameleon is always followed by a darkening of the region of skin thus denervated through a dispersion of pigment in its dark color-cells. In the pale state of the animal the pigment in these cells was believed by Brücke to be kept concentrated by the action of nerves. When these were cut this activity was lost, the color-cells were believed in consequence to relax, and the pigment then spread throughout their interiors, thus darkening the given area of skin. From this standpoint the concentrated condition of the pigment was believed to indicate the active state of the color-cells and the dispersed condition their state of rest. The cutting of a cutaneous nerve according to Brücke really paralyzes the color mechanism, a view still held by certain recent students of this subject (Sand, 1935). Brücke's nervous interpretation of animal color changes was adopted by Lister who in 1858 published a very full account of the chromatics of the common European frog. In this paper Lister pointed out the great importance of the eyes as the receptive organs for color reactions and declared that his experiments indicated pretty clearly that these organs "are the only channels through which the rays of light gain access to the nervous system so as to induce changes of colour in the skin." This conclusion was subsequently arrived at independently by Pouchet who, in a most important series of papers issued between 1871 and 1880, demonstrated the necessity of the eyes for color responses in fishes and in crustaceans and showed further that in the fishes the chromatic system was dependent upon sympathetic or, as they are now termed, autonomic nerves. These general views were supported and extended by von Frisch (1911, 1912) in an admirable series of studies on the color changes of fishes. Thus was brought to full development what may be called the purely nervous interpretation of animal color changes.

Meanwhile another line of approach to this subject had been developing. In 1898 Corona and Moroni discovered that adrenaline when injected into a frog would induce profound color alterations. This unique observation was subsequently confirmed by Lieben (1906) who made a more extended investigation of the subject. Comments by Fuchs (1914) on these two pieces of work led Redfield (1918) to study the effects of adrenaline on the chromatophores of *Phrynosoma* with the result that this hormone was found to be a potent agent in inducing chromatic responses.

Another like substance was shortly thereafter discovered. Through the work of Adler (1914), of P. E. Smith (1916), and of Allen (1917) the technique of hypophysectomy on larval amphibians was perfected and it was pointed out that individuals thus bereft of their pituitary glands were always pale in color. The significance of this

condition for color changes in general was indicated by Atwell (1919). Two years later Swingle (1921) noted that tadpoles became dark when a part of the pituitary gland was implanted in them, and the next year the blanching of the common frog after the removal of its pituitary body was recorded by Krogh (1922). Meanwhile Hogben and Winton (1922) were led through these and similar investigations to an intensive study of the pituitary secretions in relation to chromatic changes with results that were truly revolutionary. These results when coupled with the generally negative outcome of experimental nerve cutting in amphibians led Hogben to conclude (1924) that the color changes in these animals involve direct innervation only to a very slight degree, if at all, and depend primarily upon fluctuations in the amount of pituitary secretion in the blood of the creatures. Thus in amphibians at least the nervous interpretation of chromatophoral control was in large part abandoned for one based upon a pituitary substance in the form of a hormone.

Soon after amphibian color-cells had been shown to be under humoral control, crustacean chromatophores were found to be similarly influenced. In 1925 Koller noticed that the coloration of the shrimp *Crangon* could be quickly changed by alterations in its food, a fact which led him to experiment with blood transfers. As a result he declared that when the blood of a dark shrimp was injected into a pale one the recipient quickly became dark, though blood from a pale shrimp when injected into another pale one had no influence whatever on the color of the latter. Hence Koller concluded that the color changes in crustaceans were influenced and perhaps controlled by internal secretions rather than by nerves. In 1928 Perkins, whose extended studies on the effects of nerve-cutting on the color changes in *Palaemonetes* had led to only negative results, made the important discovery that extracts of the eye-stalks of this shrimp when injected into a dark individual caused it to blanch though they were without color effect when injected into other pale individuals. This discovery was confirmed in *Crangon* by Koller (1928) who claimed further that a darkening hormone could be obtained from the rostral region of the species of shrimp upon which he worked. The presence of a blanching eye-stalk hormone was soon confirmed in a number of crustaceans by several investigators who, however, were unable to find good evidence of the darkening agent originally described by Koller. In all this work on crustaceans not the least support was found for the nervous control of their color-cells so that in these animals, as in amphibians, the color effectors appeared to be controlled by humoral substances. Notwithstanding the validity of this conclusion and the subsequent growth of evidence in favor of it the fact remained that in many fishes and reptile chromatic responses were accomplished by direct nervous means. This led to a view held by not a few investigators at that time that the control of chromatophores was not a uniform matter, but varied in different groups of animals, in some humoral, in others nervous.

A new approach to this subject was independently suggested by two workers in this field (Giersberg, 1930; Parker, 1932) one of whom was led to develop this novel view more fully (Parker, 1935a, 1935b, 1936c, 1940a). According to this more recent conception the initial step in the color changes of actively chromatic animals is an appropriate stimulation of the eyes from which nervous impulses pass either to glands of internal secretion whose products thus excited are carried by the blood to the chromatophores, or they pass over nerves to their chromatic terminals the secretions of which act upon the neighboring color-cells and thus induce them to respond. From this standpoint both humoral activation and nervous activation are dependent upon secreted substances either from remote glands or from nearby nerve terminals, conditions which do much to obliterate the distinction between the so-called humoral and nervous methods of excitation and bring the whole subject of chromatophore activation in line with the modern conception of internuncial transmission by chemical agents.

The activating substances involved in these excitatory transfers which are believed to occur between one neurone and another or a neurone and its terminal effectors such as muscle cells, gland cells, chromatophore or the like, have been variously designated as neurohumors (Fredericq, 1927; Parker, 1932), transmitters (Dale, 1935), neurohormones (Huxley, 1935), and chemical mediators (Cannon and Rosenblueth, 1937). But however they have been named they partake of the same nature in that they are substances that originate in one region and pass in a dissolved state to another where they become effective though the space thus traversed may be in some instances microscopically small. Adopting the general designation of

neurohumors for such agents this term may then be defined as embracing those hormones produced by nervous tissue or by glands appended to that tissue and serving as activators or inhibitors of other nervous tissue or its effectors such as muscles, glands, luminous organs, chromatophores, and the like (Parker, 1940b). The doctrine that such substances exist and act in the way implied in this definition may be conveniently designated as neurohumoralism and the question discussed in the following pages is the extent to which this conception is justified by what is known of chromatophoral activation.

II. THE ELEMENTS IN THE COLOR SYSTEMS OF ANIMALS

Aside from a few sporadic cases of color change among such animals as the sea-urchins, the leeches, and the insects, this type of change is to be met with only in three major groups of the animal kingdom: the cephalopods, the crustaceans, and the cold-blooded vertebrates, including the fishes, the amphibians, and the reptiles. Of these the fishes have been perhaps the most intensively investigated and will serve in the main as the subject matter for the following account. The chromatophoral systems in fishes are especially rich in their types of color-cells. Of these the most usual are chromatophores containing granules of black pigment and hence known as melanophores. In addition to these there are three other common kinds of color-cells: xanthophores (yellow), erythuprophores (red), and leucophores (white). A number of animals possess in addition to these color-cells small clusters of semi-crystalline plates the tints of which are of jewel-like brilliancy. Such a cluster is usually surrounded more or less completely by a melanophore whose activities may expose or cover the glistening bodies. Complex color elements of this kind have been designated as chromatosomes. They are concerned chiefly with the bluish and greenish tints of fishes, whereas the other types of color-cells have to do with the red, yellow, and gray tones. The commonest change of all is that from pale to dark gray which results from the activity of the melanophores. Because of the ease with which this color change can be observed it is the one most usually recorded.

A good example of melanophore changes and their effects on the colors of fishes is shown in Fig. 1 from the common catfish *Ameiurus*. In the top section of the figure (A) is shown the range of tints of this fish from the pale extreme of a translucent greenish yellow to the opposite one of coal black. The remaining sections of the figure (B to G) show the states of the melanophores for three of these tints. *Ameiurus* has two kinds of dark color-cells, macromelanophores in the derma (B, D, F) and micromelanophores in the epidermis (C, E, G). In fishes of extreme paleness (A, right-hand specimen) the melanophore pigment is most concentrated so that the macromelanophores appear as large dots (B) and the micromelanophores as small ones (C). In coal-black individuals the pigment has spread throughout the cell processes of the melanophores, the many processes of the large melanophores (F) and the few of the small color-cells (G). In fishes of intermediate tint (middle fish in group A) the spread of pigment in both kinds of color-cells is intermediate in amount (D and E). These figures give a clear idea of the states of the melanophores in relation to the tints that *Ameiurus* may assume.

1. Primary color responses

In the lower vertebrates color changes make their appearance at a very early stage of development sometimes before the young animals have hatched from the egg. Babák (1910) noted the first appearance of these changes in the Mexican axolotl when it was 1.5 cm. long. In complete darkness these young animals were pale and in bright light they were dark. But when they had attained a length of 5 cm. they were almost the reverse of this in that in complete darkness they were dark and in bright light they were either pale or dark depending upon their surroundings, pale on a white background, dark on a black one. Of the two general conditions the early larval one was called the primary color phase, the succeeding one the secondary phase. When a larva in the secondary phase was blinded it was found to revert to the primary phase. When a young larva in the primary phase was deprived of its eyes it retained its capacity for that color phase without alteration. It was Babák's belief that the primary phase was due to the direct stimulation of the color-cells, melanophores, by light and that the secondary one resulted from the indirect stimulation of these cells through the eyes. Although Babák's explanation of the primary phase has been rejected in certain instances (chameleon, Zoond and Eyre, 1934; ammocete, Young, 1935) his idea of the sequence of a primary by a secondary one has been shown to

occur in many animals as, for instance, in pleuronectids (Wenckebach, 1886), in axolotls (Pernitzoch, 1913), in *Rana pipiens* (Hooker, 1914), in several species of *Amblystoma* (Laurens, 1914), and pointed out some lower vetebrates appear to have abbreviated the development of their color sequence by the suppression of the primary phase. Examples of this condition have been noted in

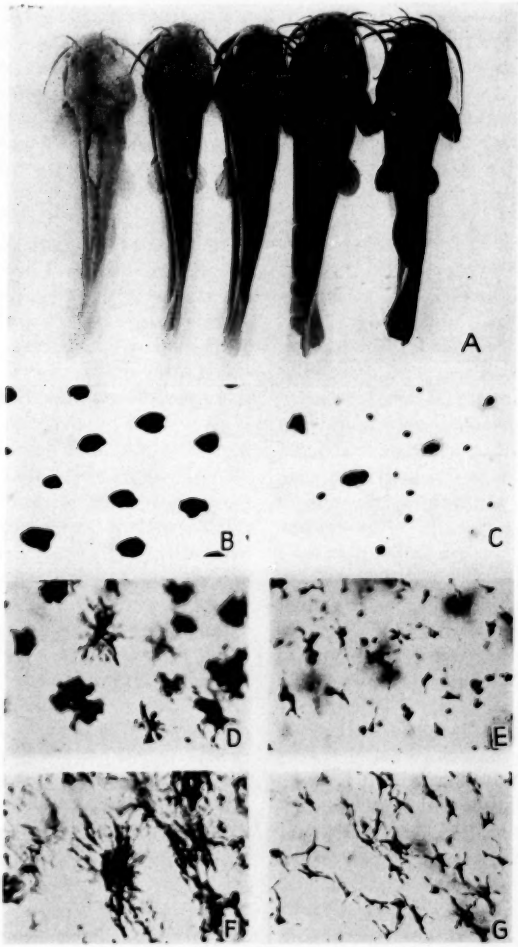


FIG. 1. RANGE OF TINTS FROM EXTREME PALE TO EXTREME DARK (A) IN THE CATFISH AMEIURUS AND THE CONDITIONS OF ITS COLOR-CELLS (B TO G) AT THREE STAGES

Macromelanophores (B) from derma and micromelanophores (C) from epidermis from fishes of palest tint showing maximum concentration of pigment. Large (F) and small (G) melanophores from coal-black fishes showing maximum dispersion of pigment. Conditions of the two kinds of melanophores (D and E) from fishes of intermediate tint.

in several other amphibians (Fischel, 1920), in *Perca* (Duspira, 1931), in *Macropodus* (Tomita, 1936), in two species of *Salmo*, *S. salvelinus* (Duspira, 1931) and *S. trutta* (Neill, 1940), and in *Hoplias* (Mendes, 1942). As Babák himself *Bombinator* and in *Hyla* (Babák, 1910), in *Fundulus* (Bancroft, 1912; Spaeth, 1913; Wyman, 1924; Gilson, 1926;), in *Lebistes*, *Gambusia*, and *Xiphophorus* (Tomita, 1936), in *Mustelus* (Parker, 1936a), in *Scyllium* (Waring, 1942) and in *Xenopus* (Land-

grebe, quoted by Waring, 1942). *Onchorhynchus* has been relegated to this group by Tuge (1937), but it is more probable that this fish is a member of the first group whose response to darkness develops late in ontogeny as compared with that to light. Laurens reports *Amblystoma tigrinum* as a species that remains throughout life in the primary phase. It is interesting to note that no instance is known among chromatic vertebrates in which there is a secondary phase followed by a primary one. This is in accordance with what is implied in Babák's general conception of the relation of these two states.

As Babák first pointed out when a chromatic vertebrate has passed into its secondary phase and is blinded it commonly lapses into the primary one. This condition has been identified in a considerable number of forms: in *Rana esculenta*, *R. fusca* (Babák, 1910), in several species of *Amblystoma* (Babák, 1910, 1912; Laurens, 1914, 1915), in *Triton* and *Salamandra* (Fischel, 1920), in *Xenopus* (Slome and Hogben, 1928, 1929), in *Macropodus*, *Lebistes*, *Gambusia* and *Xiphophorus* (Tomita, 1936) and in *Phrynosoma* (Parker, 1938a). Thus a considerable body of evidence direct and indirect supports Babák's original claim of primary and secondary phases of color response in the lower vertebrates. Whether the changes in the primary phase are induced by the direct stimulation of the color-cells by light as believed by a number of workers (see Parker, 1938a) or are due to other forms of activation (Zoond and Eyre, 1934; Zoond and Bokenham, 1935; Kleinholz, 1938b) remains uncertain. Nor has any clear view been expressed as to the biological significance of the primary color phase, which as the examples quoted show, presents itself most strikingly just before or after the young animal has hatched. The possible intervention of neurohumors in these changes has not even been suggested.

2. *Secondary color responses*

A. Introduction

Secondary color responses are characteristic of larval life, especially late larval life, and in general of the adult period. They are often lost in creatures in full maturity or in old age. They are dependent upon the functional activity of the eye as can be shown by their disappearance in completely enucleated animals. Their immediate induction may result from nervous or from humoral agents, or from a combination of these. Before 1915 all such color responses were believed to be exclusively under nervous control. This belief was in accordance with the findings of such early investigators as Brücke, Lister and others, nor is it entirely without truth today. From this standpoint three classes of chromatophores (melanophores) may be distinguished: those with double innervation (dineuronic chromatophores), those with single innervation (mononeuronic chromatophores), and those without innervation (aneuronic chromatophores).

B. Dineuronic chromatophores

That chromatophores and especially melanophores may have two kinds of innervation, one concerned with the concentration of their pigment and the other with its dispersion, is by no means generally admitted. In a recent survey of this subject Waring (1942) states that although there is no intrinsic unlikelihood of double innervation, the evidence in favor of such a type of nerve supply is insufficient. The evidence is very different depending upon which type of nerve-fiber, concentrating or dispersing, is being considered.

The presence of concentrating nerve-fibers in many chromatic vertebrates, especially in teleosts, is one of the most generally accepted facts in color physiology. The evidence upon which this belief rests turns on the results of electric stimulation of nerves and nerve-tracts as practised by even the early investigators (Brücke, 1852; Pouchet, 1876). When appropriate nerves, nerve-tracts, or nerve centers are stimulated electrically, a given part of the animal tested or under certain conditions the whole of it blanches with great regularity. If previous to such a test a part of the skin of the experimental creature is denervated, the blanching will in no instance affect the part thus devoid of nerves. This general type of response has been recorded repeatedly in fishes and reptiles by numerous recent workers: in fishes by von Frisch (1911), Spaeth (1913), Schaefer (1921), Wyman (1924), Parker (1935c), Abramowitz (1936b), Osborn (1938), Wykes (1938), Parker and Rosenblueth (1941), and Hunter and Wasserman (1941), and in reptiles by Redfield (1918), Hogben and Mirvish (1928a, 1928b), Sand (1935), and Parker (1938a). Since in this type of blanching the color change never spreads into a denervated area, it cannot be due to a concentrating hormone carried in the blood but must result from nerves acting locally on the color-cells. The evidence for this

view is now so complete that, as stated at the opening of this section, no result in chromatic physiology is more generally accepted than the presence in many lower vertebrates of the concentrating type of nerve-fiber (Sand, 1935).

Evidence for dispersing nerve-fibers in these lower forms is of recent date and not so commonly admitted. From the time of Brücke it has been generally maintained, as stated in the Historical Introduction to this article, that the dark areas of skin induced by the cutting of cutaneous nerves result from a paralysis of the concentrating fibers. The probable incorrectness of this view, however, can be shown experimentally. If a dark band is induced in the tail of a pale killifish, *Fundulus heteroclitus*, by cutting a bundle of radiating

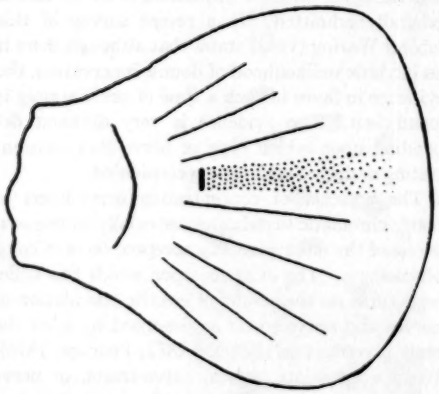


FIG. 2. DIAGRAM OF A CAUDAL FIN OF A KILLIFISH, FUNDULUS, SHOWING A BAND OF DARK MELANOPHORES PRODUCED BY CUTTING RADIAL NERVES NEAR THE ROOT OF THE TAIL (Parker, 1934a.)

caudal nerves (Fig. 2) and the fish is kept in a white, illuminated vessel, the band will fade in a few days (Parker, 1934a). This kind of blanching in fishes was first pointed out by Pouchet (1876). It was also noticed by von Frisch (1911), but neither Pouchet nor von Frisch gave it any special consideration. If after such a caudal band has blanched, a new transverse cut is made within the area of the old band and slightly distal to the original cut, a second band will appear reaching from the new cut over a part of the original band to the edge of the tail (Fig. 3). Such a revival of the greater part of the old band is a very significant fact and leads to two important conclusions. The first is that that portion of the chromatic apparatus that has been severed from the central nervous system by the first cut is by no means paralyzed, as was claimed by Brücke, but is capable of full, even of excessive activity. And the second conclusion is that since the original cut must have obstructed completely all central influences such as tonus and the like the revival of the band by the second cut must be due to a local stimulation of elements in the severed nerve. Since under this kind of stimulation the melanophores of the band disperse their pigment the elements activated by the new cut must be dispersing nerve-fibers. It is therefore concluded that the chromatic nerves of *Fundulus* contain dispersing as well as concentrating nerve-fibers (Parker, 1934a).

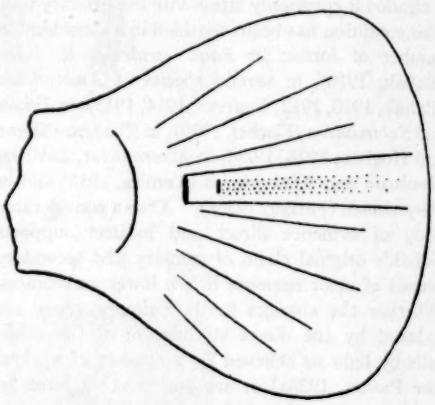


FIG. 3. DIAGRAM OF A FADED BAND IN THE TAIL OF A KILLIFISH WITHIN WHICH A NEW, SHORT, TRANSVERSE CUT HAS BEEN MADE

This cut induced the formation of a new small band within the larger one showing that the severed nerve-fibers of the original band were still active. (Parker 1934a.)

Since the attention of workers was first called to the revival of faded caudal bands by recutting, this phenomenon has been recorded in a number of fishes. It was noted in the melanophore system of *Parasilurus* by Matsushita (1938), of *Pterophyllum* by Tomita (1938, 1940), and of *Ameiurus* by Parker (1941a), and in the erythrophore and xanthophore systems of *Holocentrus* by Parker (1937c) and of *Gobius* and of two species of *Fundulus* by Fries (1942a, 1942b). The inability of Wykes (1938), of Osborn (1938), and of Vilter (1938, 1939a, 1939b) to revive by recutting the blanched bands in the teleosts studied by them appears to have been due either to the low tempera-

tures at which they worked or the lateness when their tests were applied (Parker, 1941a), for the fishes which these investigators studied unsuccessfully have since yielded positive results in the hands of other workers. Furthermore, dispersing nerve-fibers have been recently demonstrated by appropriate electrical stimulation of the caudal nerves in *Ameiurus* (Parker and Rosenblueth, 1941). Thus the evidence from both nerve cutting and electrical stimulation favor the view that dispersing as well as concentrating nerve-fibers are contained in the chromatophore systems of a number of teleosts.

That the pituitary secretion is not necessarily involved in the tests for dispersing nerve-fibers is seen when such tests are carried out on hypophysectomized fishes. As early as 1933 Matthews showed that *Fundulus* after hypophysectomy could still change from pale to dark and the reverse on appropriate change of background. As the part of the chromatic mechanism left in *Fundulus* after the removal of its pituitary gland is the nervous portion, its change to a dark shade when on a black background must be ascribed to dispersing nerve-fibers. The same in general is true of *Ameiurus* though with an interesting difference. When the pituitary gland is removed from *Ameiurus* and the fish is kept for a number of days till it has recovered from the operation and all traces of pituitary secretion have disappeared from its blood, it will still change color with change of background. The change from pale to dark, however, is never fully carried out but stops about midway between the extremes of full pale and of dark to remain at an intermediate gray tone. This incomplete darkening, which was first noticed by Abramowitz (1936b), must result from the unassisted action of dispersing nerve-fibers. It can be completed to full darkening by the injection into such a gray fish of a sufficiency of pituitary extract (Parker, 1941a). The darkening of *Fundulus* and of *Ameiurus* under the circumstances described affords strong evidence of dispersing chromatic nerve-fibers in these teleosts which, since they are also possessed of concentrating fibers, must afford instances of double innervation of chromatophores.

Still other lines of evidence favor dineuronic color-cells in teleosts. Thus the pharmacological studies of the chromatophores in *Phoxinus* by Giersberg (1930) and in *Fundulus* by D. C. Smith (1931) indicate double innervation in these fishes. The same is true of Mill's investigation (1932) of the melanophores on the edges of the caudal bands in *Fundulus* when the fish in general is either pale or dark. Under these circumstances individual melanophores are to be seen that fail to show either fully dispersed or fully concentrated pigment, a condition indicative of the loss of one but not both of the two sets of chromatic fibers. Similar evidence has also been put forward by Abramowitz (1936a) in his study of the regeneration of chromatic nerves in *Fundulus*. When the regenerating front in a partly renewed caudal band is studied in this killifish either pale or dark, melanophores will be found on the regenerating edge with dispersing or concentrating capacity but not both, a state somewhat like that seen by Mills and difficult to explain except on the assumption of double innervation. Thus other lines of evidence than those given in the preceding paragraphs lead to the conclusion that the melanophores of a number of teleosts have dispersing as well as concentrating nerve-fibers. This conclusion is fully in accord with the histological findings of Ballowitz (1893) who long ago demonstrated that each melanophore in such fishes as the perch was surrounded by a host of chromatic nerve terminals derived from not one but several nerve-fibers one of which might well be a concentrating fiber and another a dispersing one (Fig. 4).

From this standpoint the melanophores of teleosts appear to resemble the heart muscle of the higher vertebrates in that they possess opposing sets of nerve-fibers. These fibers, like those for the heart, are from the autonomic system and have been suspected of being sympathetic and parasympathetic in character. Whether such distinctions hold in these rather remote parts of the autonomic field may well be doubted, but that two sets of opposing nerve-fibers are present in this particular part of the system seems beyond doubt. Double innervation of chromatophores is apparently limited to bony fishes though it may possibly occur among such reptiles as the chameleons (Parker, 1938a) where in fact it was originally suspected by the French physiologist Bert (1875). The idea of double innervation of chromatophores as restated a decade or so ago (Mills, 1932; Parker, 1934a) was rather vigorously opposed by some workers (Sand, 1935), but in the course of the last few years it has become more generally accepted by a number of important investigators in this field (Dalton and Goodrich, 1937; Tuge, 1937; Chang, Hsieh, and Lu, 1939; Healey, 1940; Tomita, 1940;

Fries, 1942a, 1942b; Lee, 1942). The insufficiency of the evidence in favor of this view seems to have impressed few but Waring (1942).

C. Mononeuronic chromatophores

Color-cells with a single type of innervation are characteristic of cephalopods and of at least two vertebrates, the smooth dogfish, *Mustelus*, and the horned toad, *Phrynosoma*.

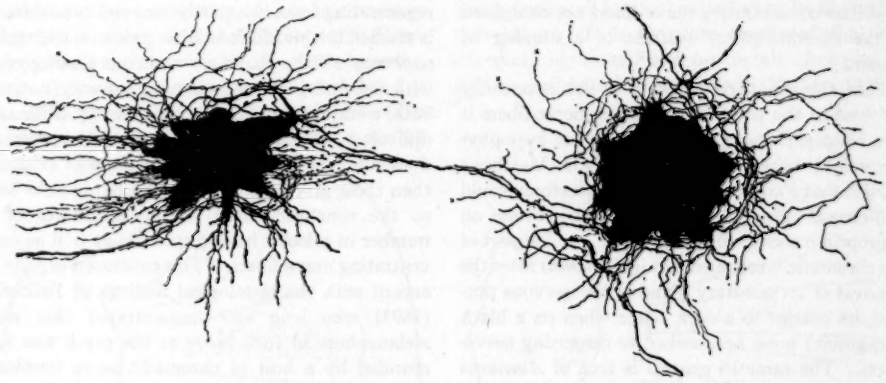
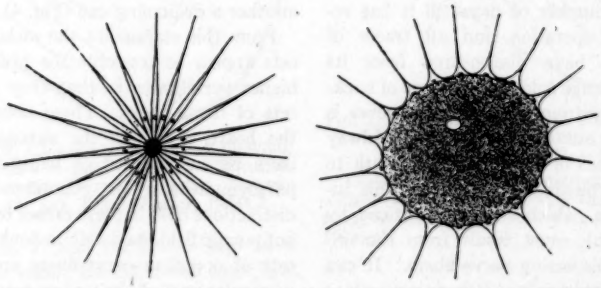


FIG. 4. INNERVATION OF TWO MELANOPHORES IN THE PERCH (Ballowitz, 1893.)



a b

FIG. 5. CHROMATOPHORES OF THE SQUID LOLIGO; A, CONTRACTED; B, EXPANDED (Bozler, 1928.)

In the cephalopods such as the devil-fishes and the squids the chromatophores are of an entirely different type of structure as compared with those in other animals. They are minute organs composed of tissues, pigmentary, muscular, and nervous, and are not single color-cells such as are of common occurrence in the crustaceans and the vertebrates. Each cephalopod chromatophore (Fig. 5) consists of a central elastic-walled sac filled with colored fluid and surrounded by a circlet of radiating, innervated, smooth muscle-fibers. When the muscle-fibers are relaxed, the sac in consequence of its elastic walls and its contained fluid assumes the shape of a sphere. When the encircling muscle-fibers contract, they pull on the equator of the sac and draw it into a disc, and since the diameter of this disc is many times that of the sphere, the color contained in the central sac is spread over a very large area compared with that of its former state. The simultaneous action of thousands of these chromatophores of one tint or another causes a blush to pass over the surface of the animal which may come and go with great rapidity. Thus a devil-fish, as described originally by Aristotle, may creep about its rocky habitat and with its ever changing tints in imitation of the light and shade of its surroundings escape its foes or catch its prey. The biology of chromatophores of this type is quite unlike that of the similarly named

parts in crustaceans and vertebrates where the general problems have to do with protoplasmic movements and not with smooth-muscle activity as in the cephalopod. Nothing more will be said about the cephalopod type of chromatophore except that its radiating muscles are controlled by a single class of nerve-fibers and that these muscles are arranged to work against the elastic pull of the central color-sac. It should be remarked that the term chromatophore, first used by the Italian naturalist Sangiovanni in 1819 in the form of chromoforo, was devised for the color organs of the cephalopods.

In the vertebrates the two forms whose color-cells have a single type of innervation are the smooth dogfish and the horned toad in both of which the cells involved are melanophores. In the smooth dogfish, *Mustelus canis*, the range of color change is from a translucent pale pink to a dark gray. This change takes place in the young in an hour or so and in the adults in about a day. As might be expected the melanophore pigment in this dogfish is fully dispersed in its dark phase and very much concentrated in its pale one. From the time of Lundstrom and Bard (1932), who were the first to study the color changes of the smooth dogfish with care, to the present (Parker, 1942) not a vestige of evidence has been found of dispersing fibers in this elasmobranch. In this respect *Mustelus* is like all other sharks and rays, about a score in number, whose color changes have been investigated. The darkening of these fishes, as will be shown later is due to the action of a hormone.

When, however, a cut is made through the pectoral fin in *Mustelus* and transverse to the course of its bundles of radiating nerves, a pale band will appear extending from the cut to near the edge of the fin and corresponding to the denervated area (Fig. 6). This band begins to show in about a quarter of an hour after the severance of the nerves, increases in distinctness for about a day, and then gradually fades till it disappears in from two to three days more. Such bands are seen best in dogfish that are of intermediate tint and particularly when they are slowly blanching. The pigment in the melanophores of such bands is much concentrated as contrasted with that in the color-cells of the adjacent skin.

More or less dispute has arisen over the occasion of the pale bands in *Mustelus*. Although the bands in many respects resemble in a local way what occurs in the blanching of *Mustelus* as a whole, the fact that they are strictly limited in area makes it highly improbable that explanations offered for the general phenomenon apply to them. For instance they cannot be due to a simple deficiency of a dispersing neurohumor such as intermedin from the blood of the dogfish (Lundstrom and Bard, 1932; Abramowitz, 1939a), nor to the presence in the blood of a concentrating one, such as the W-substance of Hogben (1936) and of Waring (1938), nor to the presence of favorable tonic impulses when a dispersing neurohumor is low in the blood (Griffiths, 1936; Vilter, 1937). All these are general influences and hence are not likely to induce local changes such as the bands are. Bands would more probably result from some such restricted change as the direct action of nerves (Parker and Porter, 1934) or of a local vasomotor disturbance

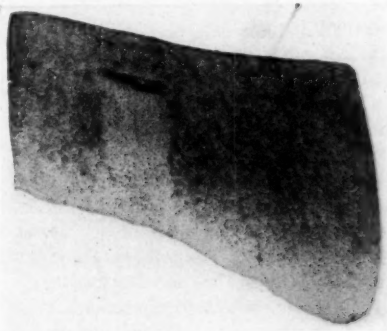


FIG. 6. PALE BAND PRODUCED BY A TRANSVERSE CUT IN THE PECTORAL FIN OF MUSTELUS

(Hogben, 1936; Waring, 1938; Abramowitz, 1939a). The fact that pale bands can be induced by nerve cutting in parts of a dogfish from which the flow of blood has been occluded by a tournique shows of what little importance the blood is in the formation of these bands (Parker, 1938b, 1940b). The pale bands in *Mustelus*, like the dark ones in teleosts, can be revived by recutting (Parker, 1936b). They can also be excited by the electrical stimulation of integumentary nerves (Parker, 1935c). When these observations are taken into account together with the fact that the pale bands follow very exactly the distribution of the nerves and not necessarily that of the blood-vessels, it appears to be very probable that they are due to the activities of concentrating nerve-fibers. As this is the only type of chromatic nerve-fiber discoverable in *Mustelus canis*, this species may be set down as

strictly mononeuronic. In this respect it seems to be unlike the majority of elasmobranchs which give no evidence of chromatic nerves whatever, though the possibility that some of these forms may possess chromatic nerve-fibers must not be forgotten (Parker, 1942).

The second chromatic vertebrate with a single type of innervation for its chromatophores is the so-called horned toad, really a lizard, *Phrynosoma*. An exhaustive study of this lizard has given no evidence that it possesses dispersing chromatic nerve-fibers (Redfield, 1918; Parker, 1938a). When its cutaneous nerves are cut, no dark areas develop. In this respect it agrees with its iguanid relative *Anolis* and is unlike the true chameleons (Brücke, 1852). On cutting or electrically stimulating the cutaneous nerves of *Phrynosoma* pale areas of appropriate location for nerves appear as they do in *Mustelus*. Thus *Phrynosoma* though far from *Mustelus* systematically is nevertheless close to this fish in its chromatic organization, a closeness which must be purely accidental and without genetic association. These three sets of animals, the cephalopods with peculiar and aberrant chromatophores and the two systematically isolated vertebrates, *Mustelus* and *Phrynosoma*, appear to constitute the present list of chromatic forms with mononeuronic organization. In the two vertebrates the chromatic nerves present are of the concentrating type. No animal is known which is chromatically mononeuronic and possessed of dispersing fibers.

D. Aneuronic chromatophores

The discovery toward the end of the second decade of this century of animals whose chromatophores were without nerves may be looked upon as one of the important turning points in animal chromatics. This condition appears to occur completely among crustaceans, imperfectly among amphibians, and sporadically among fishes and reptiles.

It is remarkable that so acute and accurate a worker as Pouchet (1876) who discovered that the eye of a crustacean was essential to its color changes should have been led to conclude that the whole course of events between eye and chromatophore was nervous even after all his tests with nerve cutting failed to disturb the normal course of color changes in such an animal. Notwithstanding this negative evidence Pouchet's belief that the chromatophores in crustaceans were under direct nervous control was handed on from investigator to investigator for nearly half a century. After thorough-going experimentation Perkins (1928) showed that the nerves of the shrimp *Palaemonetes* were in no way concerned with the animal's chromatics, but that the eye stalks of this animal discharged into its blood a substance that would blanch a dark shrimp but not change the tint of a pale one. The discovery of this hormone by Perkins substantiated the suspicion previously expressed by Koller (1925) that the color changes in shrimps were controlled by hormones and made clear the chief fact upon which crustacean chromatics has since rested. Following this initial discovery much work has been done on crustacean color changes in none of which has any evidence whatever been found for the participation of peripheral nerves in these changes. On the other hand complete confirmation of the endocrinal control of the color cells in these animals has been consistently brought forward (Kleinholz, 1942). Hence it seems perfectly clear that crustacean chromatophores are completely devoid of an effective innervation.

Among the vertebrates chromatophoral systems with no or at most few nerves characterize amphibians, many elasmobranchs, and some lizards such as *Anolis*. It will be recalled that the first group of animals in which chromatophores with little or no innervation were demonstrated was the anuran amphibians (Hogben and Winton, 1922). A very exhaustive experimental study of the color changes in frogs has given evidence of at most only a very meagre degree of chromatic control by nerves. This faint nervous control has been reaffirmed on the basis of nerve cutting and the electrical stimulation of nerves by a goodly number of workers: Elze (1923), Kropp (1927), Thörner (1929), Speranskaja-Stepanova (1930), Hafter (1932), Karasek (1933) Vilter (1936), Stoppani (1941a), and others, and on that of nervous histology by Perotti (1928). Although the chromatic responses of amphibians show by no means the complete absence of nerve control that those of crustaceans do, the nervous element in their reactions as compared for instance with that in most teleosts is so slight that they are better classed with forms devoid of color nerves than with those possessing this equipment. They appear to be vertebrates in which the nervous chromatic component has almost completely degenerated.

A considerable number of elasmobranchs, both

sharks and rays, have yielded in the hands of numerous investigators no evidence of chromatic nerves. Thus the absence of these nerves as based on the results of nerve cutting and other experimental procedure appear to characterize *Scyllium* sp. (Young, 1933), *Scyllium canicula* (Wykes, 1936; Waring, 1936), *S. catullus*, *Rhina squatina*, *Raja maculata*, *R. brachiura* (Wykes, 1936) and *R. erinacea* (Parker, 1937b). Although some of these elasmobranchs may eventually be shown to possess such nerves (Parker, 1942) the number thus far tested with negative results is so considerable that the group is probably one in which the majority of species control their color changes by other than nervous means.

Among the comparatively few reptiles the chromatic organization of which has been fully studied only the American iguanid *Anolis* appears to control its color changes without the intervention of nerves (Kleinholz, 1936, 1938a, 1938b). Transections of the spinal cord in this lizard, destruction of part of the cord by pithing as well as section of its sympathetic chains are without influence on its color changes. Individuals thus operated upon become green on a white background and brown on a black one much as normal anolids do. Hence Kleinholz was led to conclude that *Anolis* unlike other lizards, such as the chameleon and the horned toad, was completely devoid of chromatic nerves. Too few lizards have been tested in this respect to lead to any conclusion as to the generality of this state throughout the group.

A schematic statement of the chromatic elements in vertebrates as illustrated by their melanophores is given in Table 1. This tabulation summarizes the conditions under which the several types of melanophore responses occur and shows clearly how intricate the total system may be in the life of any chromatic animal as it develops from the age of primary to that of the secondary responses. The table and its descriptive heading speak for themselves.

All crustaceans, many elasmobranchs, many amphibians, and among lizards at least the anolids appear to lack effective nervous means of influencing their color changes. These animals must rely on other agents such as the special hormones known as chromatic neurohumors for the control of their color changes.

III. CHROMATIC NEUROHUMORS

1. Crustaceans

The activating substances for chromatophores without nerves belong to that special group of hormones known as chromatic neurohumors. In the crustaceans these substances are produced by glands of internal secretion for the most part located in or near the eye stalks. Of these the sinus gland appears to be the most important, though the so-called X-organ may have a share in controlling color (Hanström, 1934, 1937). Other portions of the nervous system than what are located in or about the eye-stalks may contain centers of neurohumoral secretion (Brown, 1933, 1940). Very little is known as to the number of activating substances contained in these secretions and of the properties of such substances. Extract

TABLE I

Types of response, primary and secondary, as represented in vertebrate melanophores and the conditions under which these responses take place

Abbreviations: conc. concentrating; disp. dispersing; inh. inhibition; pit. gl. pituitary gland.

I.	Primary melanophore responses
	Embryos and early larvae
	Direct action of light on melanophores (?)
A.	In light
1.	Dark animals (dispersed pigment)
B.	In darkness
2.	Pale animals (concentrated pigment)
II.	Secondary melanophore responses
	Late larvae and adults
	Indirect action of light (eyes and nerves)
C.	In light
a.	Dark animals (dispersed pigment)
3.	Black-background, eye, disp. nerves, acetylcholine
4.	Black-background, eye, pit. gland, intermedine
5.	Light on skin, integ. nerves, pit. gl., intermedine
b.	Pale animals (concentrated pigment)
6.	White-background, eye, conc. nerves, adrenaline
7.	White-background, eye, conc. nerves, selachine
8.	White-background, eye, pit. gland, W-substance
9.	White-background, eye, inh. pit. gl., intermedine
D.	In darkness
	Primary melanophore responses (?)

of eye-stalks when injected into the shrimp, *Palaemonetes*, causes a concentration of chromatophore pigment (Perkins, 1928), but when discharged into the fiddler-crab *Uca* it brings about a pigmentary dispersion (Carlson, 1936). Are these opposite effects due to different neurohumors in the extract (multiple theory) or to differences in the nature of the chromatophore responses to one neurohumor (unitary theory)? No answer can be given to this question till such extracts have been more fully analyzed. The effective material in the extracts from eye-stalks is not destroyed by boiling in water (Koller, 1930) nor in weak acid, but it is broken down by lengthy boiling in alkali (Abramowitz, 1937a). It is readily soluble in water and fairly soluble in ethyl and in methyl alcohol, but it is insoluble in a number of other common reagents (Abramowitz and Abramowitz, 1938). Its molecules must be relatively small, for they will diffuse through cellophane membranes (Carlson, 1936). It is not destroyed by drying and is therefore presumably relatively stable. Abramowitz (1937a) has proposed a measure for it in terms of *Uca* units (Abramowitz, 1939b).

2. *Vertebrates*

A. Intermedine

The chromatic neurohumors in vertebrates are somewhat better known than those in crustaceans. In the vertebrates the one neurohumor almost invariably present is intermedine (Zondek and Krohn, 1932), a product of the pituitary gland and especially of what is called its intermediate lobe. The results following the injection into chromatic vertebrates of pituitary extracts such as "pituitrin" or "infundin" as attempted by the older investigators were very contradictory. Some workers (Spaeth, 1918; Wyman, 1924; Gilson, 1926) maintained that such extracts blanched the recipients; others (Abolin, 1925; Odiorne, 1933) that they darkened the animals. This difference in results was apparently due to the impurity of the extracts used, for all recent workers without exception have shown that when the injected reagent is rich in intermedine pale animals are thereby darkened and dark animals remain unchanged. This type of response has been so invariable that intermedine is now regarded as the chief natural agent for the dispersion of melanophore pigment.

Apparently all vertebrates, chromatic or otherwise, produce intermedine, for it can be extracted from any of these animals from man to the lowest fishes, in fact even from the tunicates (Bacq and Florkin, 1935). Since it can be obtained abundantly from warm-blooded vertebrates, birds and mammals, in which no typical color changes occur, it must possess some other and probably more general function than that of pigment control.

Among the cold-blooded vertebrates intermedine is the universal darkening agent. No such vertebrate is without it though the killifish, *Fundulus heteroclitus*, can change from pale to dark about as well after hypophysectomy as before that operation (Matthews, 1933). Notwithstanding this peculiarity, *Fundulus* does produce intermedine (Kleinholz, 1935; Abramowitz, 1937b), but probably not in a sufficiency to be of functional significance in color changes. Chemically almost nothing is known about intermedine. It is evidently one of the components of what Hogben and his associates have called the B-substance. It is soluble in water and is carried in solution in the blood from the pituitary gland where it is formed to the chromatophores of the skin where it acts. The blood of a dark fish when injected into a pale one will induce the formation of a temporary dark spot, but such blood will not call forth a color change in a dark fish. Intermedine is a typical hydrohumor (Parker, 1935d). It must be a reasonably stable material, for it can be identified in the blood of a hypophysectomized fish some three days after the removal of the pituitary gland (Osborn, 1938). For quantitative work with intermedine an *Anolis* unit has been proposed and defined by Kleinholz and Rahn (1940).

B. Acetylcholine

A second chromatic neurohumor in vertebrates is acetylcholine. With this agent as with intermedine the tests of the earlier workers gave little uniformity. Barbour and Spaeth (1917), Wunder (1931), and Smith and Smith (1934) reported no chromatic response to acetylcholine. Parker (1931) suspected a slight melanophore expansion, but on change of technique by the introduction of eserine he noted (1934b) a slight contraction, a view subsequently espoused by Bogdanovitch (1937) and by Beauvallet (1938). It now appears after extended trials that this neurohumor disperses melanophore pigment and thereby darkens vertebrates (Chin, 1939; Chang, Hsieh and Lu, 1939; Parker, 1940c; Mendes, 1942). Acetylcholine when injected into a fish is rapidly destroyed by the cholinesterase of the animal's tis-

sues. To prevent this destruction it is necessary to prepare a chromatic vertebrate for the reception of acetylcholine by a preliminary injection of eserine. In the common catfish, *Ameiurus*, one part of eserine by weight may be injected for every 200,000 parts by weight of fish. In a series of catfishes thus prepared each individual received 0.2 cc. of solutions of acetylcholine of different concentrations from 1 part of the reagent in 100 parts of Ringer's solution to 1 part in 100,000,000,000 parts of solvent. The weakest of these mixtures had no effect on the color of the fishes. All others darkened them and the strongest two eventually brought on death to them. The satisfactory range of the solutions for physiological tests was from 1 part in 10,000 to 1 part in 1,000,000,000. The darkening that resulted from these various concentrations usually required from 20 minutes to half an hour to reach its maximum (Parker, 1940c).

Can acetylcholine be identified in the skin of a dark catfish? This can be tested by the use of strips of leech muscle. The responses of a preparation of leech muscle to extracts of dark catfish skin can be compared with those of the same preparation to standard solutions of acetylcholine. By this means it was found that on the average 0.078 gamma of acetylcholine was contained in 1 gram of wet, dark, catfish skin or roughly 1 part of acetylcholine in 13,000,000 parts of skin (Parker, 1940c). While this determination was in progress Chang, Hsieh and Lu (1939) published a similar determination on the skin of the snake fish, *Ophiocephalus*, in which the amount of acetylcholine was shown to be 0.077 gamma per gram of skin. Although the close agreement of these two determinations must be in a measure accidental, they are confirmatory one of the other and show at least the order of magnitude of the amount of acetylcholine in dark fish skin. They also indicate how enormously efficient this neurohumor is. It is not without interest to note that the amount of acetylcholine found in the skin of the catfish would result from the injection into a 50 gram fish of 0.2 cc. of a mixture of 1 part of acetylcholine in 52,000 parts of solvent, a concentration within the limits of the physiologically effective mixtures already mentioned, namely 1 part in 10,000 and 1 part in 1,000,000,000 (Parker, 1941a).

Although acetylcholine has thus been demonstrated in the dark skins of snake fishes and of catfishes in amounts that will darken them, it has not been shown definitely to be a product of the dispersing integumentary nerve-fibers. Nor has it been shown that this neurohumor is absent from pale skin as might be expected. This step though attempted has not been carried out with success for the reason that the removal of a pale skin involves the cutting of all its integumentary nerves which renders the skin dark before it can be used in a test and thus precludes the possibility of a final determination (Parker, 1940c). These two important deficiencies must be made good by further research.

Acetylcholine is a choline derivative the functional efficiency of which is enormously increased by acetylation. Its molecules are relatively small and readily inactivated by the cholinesterase of animal tissues. It is soluble both in water and in oils and can therefore act either as a hydrohumor or as a lipohumor. When dissolved in the lipoids of the tissues, it is protected for a considerable period from destruction by cholinesterase (Parker, 1940c). Both acetylcholine and intermedine are present in the catfish whose normal darkening is first accomplished under the influence of acetylcholine and then under that and intermedine. This sequence illustrates the well-known principle that color changes are carried out more quickly by nerves than they are by blood-borne neurohumors. Acetylcholine and intermedine are the two most important constituents in what Hogben has designated as B-substance.

C. Adrenaline

A third chromatic neurohumor in vertebrates is adrenaline. As noted in the introduction to this article adrenaline was the first hormone to be used experimentally in tests on animal color changes (Corona and Moroni, 1898). It is produced by the medulla of the adrenal glands in the higher vertebrates, by the chromaffine tissue scattered or segregated in the tissues of the lower vertebrates, and by their concentrating chromatic nerve-fibers. Its general function of mobilization of resources for excessive activity (Cannon) is commonly admitted. Its chromatic action as judged by injection is concerned with the concentration of melanophore pigment and the consequent blanching of the animal. but this type of response is by no means invariable, Kleinholz (1938a) has pointed out that in *Anolis* adrenaline not only causes a generalized pallor but also induces in this lizard certain dark patches and mottlings and Bigney (1919) showed that on injec-

tion into the frog it induces a concentration of pigment in integumentary melanophores but a dispersion of it in retinal pigment-cells. Thus even in the same animal adrenaline produced opposite effects. Notwithstanding these exceptional instances the injection of adrenaline into a chromatic vertebrate is in most instances very regularly followed by a concentration of melanophore pigment (Pierce, 1941, 1942). It is probably the natural agent in the blanching of these animals, but a definite determination of this point has been made in relatively few forms (*Phrynosoma*, Redfield, 1918; Parker, 1938a; *Anolis*, Kleinholz, 1938a; *Ameiurus*, Abramowitz, 1936b; Parker, 1940c; *Bufo*, Stoppani, 1941b). It appears to be associated in numerous vertebrates with what is known as excitement pallor (Hogben and Mirvish, 1928a, 1928b). It acts directly on integumentary melanophores (Parker, 1934c) and as a blanching agent it is a functional opponent to intermedine and acetylcholine. One difficulty in its study is that the concentration of pigment that can be induced by it can often be brought about by the withdrawal of intermedine from the blood of a given vertebrate. Adrenaline is a secondary alcohol which was synthesized over two decades ago. Its molecules are relatively small. It may well represent the W-substance of Hogben and be derived from such sources as the pars tuberalis of the pituitary complex (Hogben and Slome, 1931, 1936; Hogben, 1936). It can act both as a hydrohumor and a lipohumor (Parker, 1940c).

D. Selachine

This neurohumor occurs in the smooth dogfish, *Mustelus canis*. In conjunction with the loss of intermedine from the blood of this fish it is believed to be responsible for the full blanching of *Mustelus*. No evidence of it is found in the blood of pale dogfishes nor can it be detected in aqueous extracts of their pale skins. There is therefore no reason to suppose it to be a hydrohumor. Olive oil extracts or ether extracts hot and cold, when injected into pale or dark *Mustelus*, produce very pale temporary spots due to the concentration of melanophore pigment (Fig. 7). Selachine is therefore believed to be a true lipohumor and to act directly on melanophores. It spreads very slowly through the skin of the dogfish as is indicated by the change of form of the pale spots induced by it. It presumably passes in solution through the lipoid constituents of the skin of this fish. Almost nothing is known of its properties excepting its limited solubility and the fact it will withstand lengthy heating at 110° C. (Parker, 1942).

E. Sympathine

Whether Cannon's sympathine is to be placed among the chromatic neurohumors of vertebrates as Vilter (1937), and Chang and Lu (1939) have done with it is an open question. In discussing

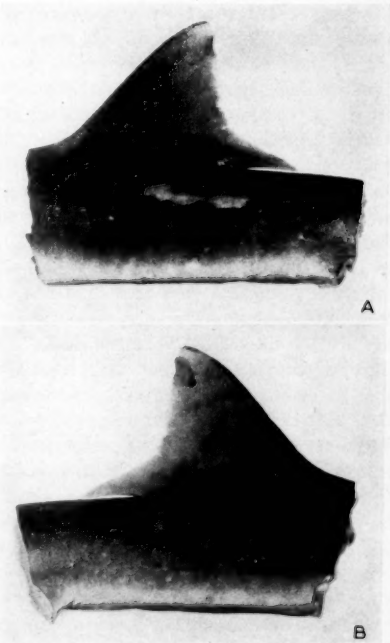


FIG. 7. A. LEFT SIDE OF THE TRUNK OF A SMOOTH DOGFISH, MUSTELUS, IN THE REGION OF THE ANTERIOR DORSAL FIN SHOWING A LIGHT SPOT DUE TO AN INJECTION OF 0.5 CC. OF AN EMULSION OF OLIVE-OIL EXTRACT OF BLANCHED FINS AND SEAWATER

B. RIGHT SIDE OF THE SAME FISH SHOWING NO CHANGE OF COLOR AFTER THE INJECTION OF 0.5 CC. OF AN EMULSION OF OLIVE-OIL AND SEAWATER

adrenaline as a neurohumor two general sources were mentioned, the medulla of the adrenal gland with other less defined chromaffine masses and the concentrating chromatic nerve-fibers. It is not impossible that the substance here described as adrenaline from the chromatic fibers is sympathine, but this question must be left for further investigation.

Undoubtedly other neurohumors than the five

here mentioned will be found to be concerned with the color changes of vertebrates, but such additional agents will probably be of secondary significance as selachine and sympathine seem to be. The color changes in the vertebrates appear to be controlled in the main by three of the five substances named: the darkening agents intermedine

lopods and the crustaceans, has scarcely been touched upon and in the vertebrates only a beginning in this field has been made. As the preceding account shows, vertebrate melanophores are controlled in the main by either nerves, concentrating or dispersing, or by certain glands of internal secretion, chiefly the pituitary complex.

TABLE 2

Elements concerned with particular color changes in a score of vertebrates as indicated by the names of the authors who recorded the determining responses and dates of their publications

Abbreviations: A, element absent; P, element present; blank, condition untested; 1, selachine; other responses recorded in this column due presumably to adrenaline; 2, unpublished determination by recutting of nerves; 3, adrenal gland.

	ACTIVATING ELEMENTS			
	Nerves		*Pituitary neurohumors*	
	Concentrating	Dispersing	Dispersing	Concentrating
FISHES				
Lampetra	A. Young, '35.	A. Young, '35.	P. Young, '35.	
Scyllium	A. Young, '33.	A. Young, '33.	P. Hogben, '36.	P. Hogben, '36.
Mustelus	P. Parker *et al.*, '34.1	A. Parker *et al.*, '34.	P. Lundstrom *et al.*, '32.	
Raja	A. Parker, '36b.	A. Parker, '36b.	P. Hogben, '36.	P. Hogben, '36.
Phoxinus	P. Healey, '40.	P. Healey, '40.	P? Healey, '40.	P. Healey, '40.
Ameiurus	P. Parker, '35d.	P. Parker, '35d.	P. Parker, '35d.	A. Parker, '35d.
Parasilurus	P. Matsushita, '38.	P. Matsushita, '38.	P. Enami, '39.	
Anguilla	P. Waring, '40.	P. Parker, 2.	P. Waring, '40.	P. Waring, '40.
Fundulus	P. Mills, '32.	P. Mills, '32.	A? Matthews, '33.	
Gasterosteus	P. Hogben *et al.*, '40.	P. Hogben *et al.*, '40.	P. Hogben *et al.*, '40.	
Ophiocephalus	P. Chang *et al.*, '39.	P. Chang *et al.*, '39.	P. Chang *et al.*, '39.	
Pterophyllum	P. Tomita, '40.	P. Tomita, '40.		
Macropodus	P? Chang *et al.*, '39.	P. Kamada, '37.	P? Chang *et al.*, '39.	
Taulogolabrus	P. Hunter *et al.*, '41.	P. Hunter *et al.*, '41.	P? Hunter *et al.*, '41.	
Paralichthys	P? Osborn, '39.	P. Osborn, '39.	A. Osborn, '39.	P? Osborn, '39.
AMPHIBIANS				
Xenopus	A. Hogben *et al.*, '31.	A. Hogben *et al.*, '31.	P. Hogben *et al.*, '31.	P. Hogben *et al.*, '31.
Rana	A. Hogben *et al.*, '22.	A. Hogben *et al.*, '22.	P. Hogben *et al.*, '22.	A. Parker *et al.*, '37.
REPTILES				
Anolis	A. Kleinholz, '36.	A. Kleinholz, '36.	P. Kleinholz, '36.	A. Kleinholz, '38a.
Phrynosoma	P. Redfield, '18.	A. Parker, '38a.	P. Parker, '38a.	P. Redfield, '18. 3.
Chamaeleon	P. Brücke, '52.	P? Parker, '38a.		

from the pituitary gland, and acetylcholine from the dispersing nerve-fibers, and the blanching agent adrenaline from either the medulla of the adrenal gland or from concentrating nerve-fibers.

IV. CHROMATIC ORGANIZATION

The organization of the chromatic elements in the color systems of the lower animals, the cepha-

The particular combinations of these elements which characterize the chromatic organization of some of the better known vertebrates are shown roughly in Table 2 where the determination of the presence (P) or the absence (A) of a given element is credited to the observation of an author as designated by his name and year of publication. A question mark after the sign for presence or ab-

sence of an element implies that the evidence upon which the determination is based is not so conclusive as might be wished. A blank indicates that the presence or absence of a given element has not yet been determined by test.

The combinations of elements by which the melanophores of the several fishes recorded in Table 2 are controlled are obviously quite diverse. In some instances (*Phoxinus*, *Anguilla*) all four sets of elements appear to be involved; in others (*Rana*, *Anolis*, *Lampetra*) possibly only one set is concerned. Differences also occur in the sources of these elements. In *Raja* they appear to be all from the pituitary complex, but in *Fundulus* the taken. The consideration of such an outline naturally begins with the eye where in the eel in all probability, as in other fishes (Sumner, 1933, 1940; Hogben and Slome, 1931, 1936; Butcher, 1939; Waring, 1942), the dorsal retina is especially concerned with blanching and the ventral with darkening. As is shown in the outline (Fig. 8) when an eel is on a white background and both it and the background are illuminated from above, the eye of the fish receives light in part directly from the overhead source (L) and in part from the light-scattering, white background on which the fish rests (W). The direct light (D) falls upon the ventral retina (VR) and the scattered light (S)

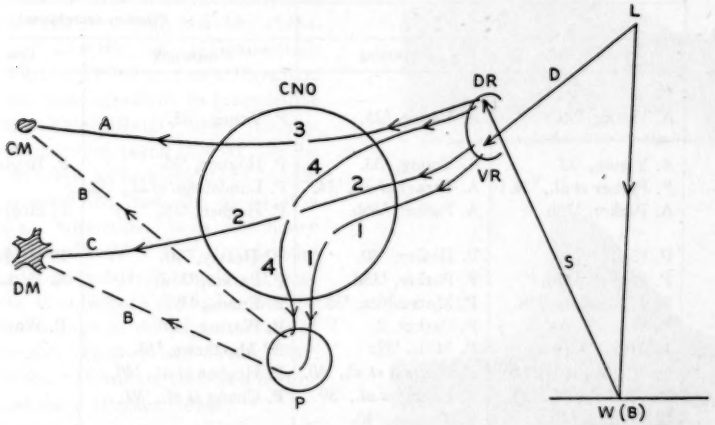


FIG. 8. DIAGRAM OF THE MELANOPHORE SYSTEM IN THE EEL (ANGUILLA)

The outer field is represented at the right, the central nervous connections. in the center, and the melanophores at the left. The reflex arcs are numbered and the special parts of the diagram are lettered. 1, Retino-pituitary arc; 2, Retino-cholinergic arc; 3, Retino-adrenergic arc; 4, Retino-tuberal arc. Abbreviations; A, adrenergic nerve-fibers; B, blood and lymph; (B) black background; C, cholinergic nerve-fibers; CM, melanophore with concentrated pigment; CNO, central nervous organs; D, beam of direct light; DM, melanophore with dispersed pigment; DR, dorsal retina; L, source of light; P, pituitary gland; S, beam of scattered light; VR, ventral retina; W, white background.

effective elements at least are from nerves. The differences shown in Table 2 are based upon the conditions presented by only one set of chromatophores, the melanophores. Were it possible to tabulate in a similar way the other types of color-cells, xanthophores, erythrophores, etc., the individual differences among the fishes would be still more pronounced.

This diversity in chromatic organization also appears when the outlines of the nervous connections that may be assumed to control the melanophore systems in the fishes named in Table 2 are compared. As a typical example of such an outline that of the eel (*Anguilla*) may well be from the white background upon the dorsal retina (DR). Under these conditions the eel, as is well known, becomes pale. When on the other hand the eel is on a black background (B) and illuminated from above, the light that enters its eye is almost exclusively the direct light from the source overhead, for the light which falls from that source on the black background is there mostly absorbed and thus fails in the main to reach the eye. Hence under these circumstances the ventral retina is the one illuminated, the dorsal one receiving little or no light. Under these conditions fishes regularly become dark. It is obvious, however, that this brief and somewhat superficial analysis scarcely

justifies the conclusion that the dorsal retina is concerned exclusively with the pale tint of the fish and the ventral one with the dark tint. More likely both retinas are more or less involved in each color phase as has been emphasized especially by Sumner who, in his discussion of this and other closely allied problems, has pointed out the importance of the ratio of the illumination on the two retinas. This relation certainly has much to do in determining the final tint of the creature. Yet for the sake of simplicity in discussing the outlines it may be assumed, as in fact Butcher (1939) and others have done, that the dorsal retina is mainly a blanching receptor and the ventral a darkening one.

If in attempting to gain some insight into the chromatic organization of the eel the reflex tracts concerned with its melanophore color changes are enumerated, they will be found to be at least four. The first of these is shown in the outline (Fig. 8, 1) as extending from the ventral retina through the brain to that part of the pituitary gland (P) concerned with the production of the neurohumor intermedine. This neurohumor here produced is then carried by blood and lymph (B) to the melanophores which are by this means brought to disperse their pigment (DM) and darken the animal. Such an arc stretching from the eye through the pituitary gland to the color-cells may be called the retino-pituitary arc. Described as a reflex mechanism, this arc is composed of two arms, one nervous from eye to gland, and the other humoral from gland to color-cell. Hence it is an arc of a neuro-humoral type (Parker, 1940d). The second arc in *Anguilla* (Fig. 8, 2) also begins in the ventral retina, extends through the central nervous organs, and as cholinergic fibers (C) makes its way with other chromatic elements over autonomic branches to the melanophores. The terminals of these fibers are believed to liberate acetylcholine which induces a dispersion of melanophore pigment and a darkening of the fish. This arc has been called a retino-cholinergic one, (Parker, 1941b) and is a typical nervous reflex arc. The third arc in the eel (Fig. 8, 3) extends from the dorsal retina through the central nervous organs and as adrenergic fibers (A) continues over the autonomic tracts to the melanophores. Its terminals produce adrenaline whereby the melanophores are excited to concentrate their pigment (CM) and thus to cause blanching. This arc, a purely nervous one, has been designated the retino-adrenergic arc. The fourth and last arc in this fish (Fig. 8, 4) extends from the dorsal retina through the brain to the tuberal part of the pituitary complex where it is believed to excite the production of the W-substance described by Hogben (Waring, 1940). This neurohumor is carried by the blood and lymph (B) to the melanophores the pigment of which is thereby induced to concentrate and blanch the eel. This arc may be termed the retino-tuberal arc and, like the first one described, is of neurohumoral type. The four arcs thus outlined give some idea of the organization of the chromatic elements in the melanophore system of the eel, a type of organization which may well characterize many teleosts.

As a second example of chromatic organization that in the catfish (*Ameiurus*) may be described. In this fish the color system is somewhat more complex than in the eel. The first, second, and third arcs described for the eel occur also in the catfish (Fig. 9). The fourth arc appears to be absent. Illuminations of the skin (I) of a catfish will cause darkening as can be shown in blinded fishes. This response is not due apparently to a direct stimulation of the melanophores, but is a true reflex (Fig. 9, 5) which originates in the photoreceptors of the integument, I (Van Heusen, 1917), passes through the central nervous organs, CNO (Wykes, 1938), and thus reaches the pituitary gland, P (Parker, 1940c). The intermedine from this gland is then carried in the blood (B) to the melanophores (DM). This fifth type of reflex is a dispersing or darkening one and may be termed a dermo-intermediate excitation arc. It is apparently active whenever the skin of the catfish is illuminated and its stimulating effect on the intermedine of the pituitary gland must be inhibited when, for instance, the catfish from being on an illuminated white background (W) blanches. Such an inhibition, as has been suggested by Chang and Lu (1939) for the snakefish, appears to depend in the catfish upon a sixth arc (Fig. 9, 6) extending from the dorsal retina through the brain to the pituitary gland. The arc is probably purely nervous and may be designated a retino-intermediate inhibitory arc. Thus in several respects the chromatic organization in *Ameiurus* differs from that in *Anguilla*.

A simpler type of chromatic organization than that of the eel is to be met with in *Fundulus*. In this fish the pituitary portion of the melanophore system, though present (Kleinholz, 1935), is func-

tionally ineffective, and the normal color changes in *Fundulus* are dependent upon adrenergic and cholinergic nerves activated from the eye. The two tracts thus indicated correspond to the second and third arcs described for the eel, the retino-cholinergic and the retino-adrenergic. The reduction of the chromatic organization in *Fundulus* to an almost purely nervous one is due in all probability to pituitary degeneration.

A second simple type of color organization occurs in *Mustelus*. Of the four chromatic arcs described for the eel two appear to suffice for *Mustelus*, the retino-intermediate and the retino-adrenergic. Of these the retino-intermediate is the more efficient commonly overriding its opponent in its effects upon the coloration of this fish (Parker, 1937a). Some workers have called in question the presence of the retino-adrenergic arc but on what appears to be insufficient ground.

The most simplified type of color organization among chromatic vertebrates is that in which there is only one reflex arc. This probably occurs in some elasmobranchs (Parker, 1942) and frogs (Parker and Scatterty, 1937; Chang and Lu, 1939) and certainly in the lizard *Anolis* (Kleinholz, 1936). It is an interesting fact that in all the examples of this type mentioned the kind of reflex arc present is the retino-intermediate (number 1 in the diagram for the eel). This arc with its neurohumor intermedine appears to be characteristic of all chromatic vertebrates, for the two exceptional cases that might be quoted, the chameleon and the killifish, are both probably incorrectly regarded as devoid of intermedine (Parker, 1938a; Kleinholz, 1935). Not only is the belief in the presence in all chromatic vertebrates of this reflex arc with its neurohumor intermedine very probable, but it is also very likely that this part of the vertebrate chromatic system is, from an evolutionary standpoint, the original part around which the other chromatic elements subsequently developed (Waring, 1942).

As the preceding survey shows uniformity in chromatic organization is not to be sought for among animals in the simple way in which the older workers looked for it. The purely nervous interpretation of these conditions has long since ceased to be tenable. Nor has the view that there are two essentially different principles of chromatophore activation, one nervous and the other hormonal (Hogben, 1924; Waring, 1942) fared much better. The conclusion that appears to have been reached is that color effectors are controlled by numerous substances, the chromatic neurohumors, some of which are from glands of internal secretion and others from nerve terminals. Occasionally as in the case of adrenaline the same neurohumor may come in one instance from a gland and in

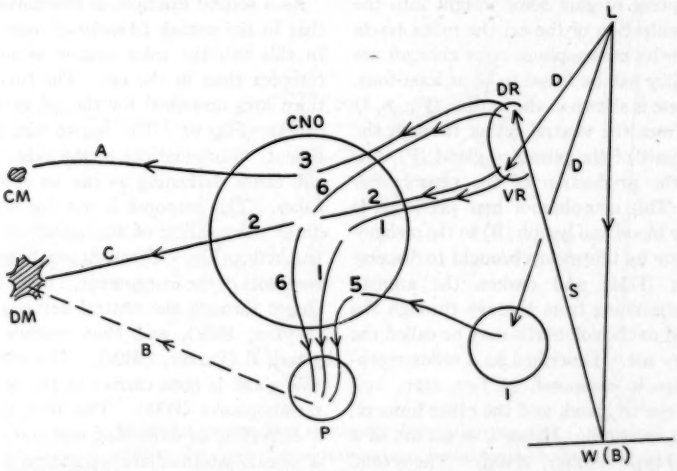


FIG. 9. DIAGRAM OF THE MELANOPHORE SYSTEM IN THE CATFISH (AMEIURUS)

The arrangement of the diagram is the same as in Fig. 8. In addition to arcs 1, 2, and 3, all of which are excitatory, there are in Ameiurus arc 5, the dermo-intermediate excitatory, and arc 6, retino-intermediate inhibitory. The lettering is the same as in Fig. 8 with the addition of I, integument.

another from nerve terminals. Thus a uniform solution of the problem of chromatic organization in animals is not to be expected.

The preceding account, intricate as it is, gives no true idea of the complexity of animal chromatics, for as here given it is based almost exclusively on a study of melanophores and most animals have in addition to these color-cells xanthophores, erythrophores, leucophores, not to mention the numerous types of chromatosomes and other complex color groupings. The control of each of these additional color effectors calls for quite as complex a neurohumoral organization as the melanophores do. When this aggregate of elements and the multiplicity of their possible combinations is kept in mind, some conception of the enormous intricacy of the chromatic system in animals can be envisaged. And yet with all this complexity the number of activating neurohumors may not be overgreat. The nature and interrelation of these agents afford the modern student of color changes an inviting field for adventure and research.

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HOMOLOGY AND ANALOGY: A CENTURY AFTER THE DEFINITIONS OF "HOMOLOGUE" AND "ANALOGUE" OF RICHARD OWEN

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"ANALOGUE. A part or organ in one animal which has the same function as another part or organ in a different animal."

"Homologue. The same organ in different animals under every variety of form and function."

These definitions are to be found in the glossary to Owen's *Lectures on the Comparative Anatomy and Physiology of the Invertebrate Animals* delivered at the Royal College of Surgeons and published in 1843. In spite of the fact that these terms form an essential part of the foundation of comparative zoology there is still much confusion in their usage. However complex the morphological and physiological characteristics of animals may be there is no excuse for a lack of precise descriptions and clear-cut comparisons of them. It is time that the implications and relations of both terms be critically examined so that we can decide upon, and adopt, their most effective meanings. Owen wrote (1866, Vol. I, p. xiii), "Terms are the tools of the teacher; and only an inferior hand persists in toiling with a clumsy instrument when a better one lies within his reach." There could be no more appropriate celebration of the centenary of Owen's definitions than the wise adoption of these terms *as he defined them*, for such action would inevitably lead us to a clearer and more effective analysis of the data of comparative zoology.

The need for reexamination of the implications of homology and analogy can be quickly shown. In the first place, the term homology was broadened by Owen and others beyond the meaning published in 1843 so that it came to refer not only to "the same organ in different animals . . ." (Owen's *special homology* (1846, 1848)) but to the essential similarities of organs along the chief axis of the body known as serial homology (Owen's homotypy (1846, 1848)) and even to the most general structural resemblances of organisms to their archetype (Owen's general homology (1846, 1848)). These extensions in meaning have led to a deplorably loose and relatively meaningless usage of the term. Thus today many texts in zoology use the term indiscriminately to refer to special or serial homology, without realizing that these two kinds of structural resemblance have an almost totally unlike significance to the zoologist. Obviously serial homologies have a very different bearing on the problems of taxonomy and genetic relationships than do special homologies for the former are intra-individual structural expressions, and no question of genetic relationship of individual organisms is involved. On the other hand, special homology most commonly signifies genetic relationship. Gegenbaur's words well express the common view, "Blood relationship becomes dubious exactly as the proof of homologies is uncertain" (1878, p. 63).

In the second place, the term analogy has had, and still has, widely differing usages. Thus, in brief, analogy has meant to zoologists (1) a similarity in function of organs whether homologous or not (Owen, Lankester, Gegenbaur, Haeckel), (2) a similarity in use of organs which are nonhomologous (MacLeay, Darwin, and most modern texts), and (3) an essential similarity in structure (Geofroy Saint-Hilaire, Cuvier, Dumeril, and other French 19th century zoologists). But if the meanings of analogy have been so various, what of the relations of the terms homology and analogy to each other? Here the human instinct for bungling terms has reached its fullest expression! It has been so bad that even the same writer has contradicted himself in a single paragraph, as shown, for example, in the following quotation from Sir William Turner (*Encyclopedia Britannica*, 9th ed., 1899. New American Supplement, Vol. I, p. 830, article *Anatomy*).

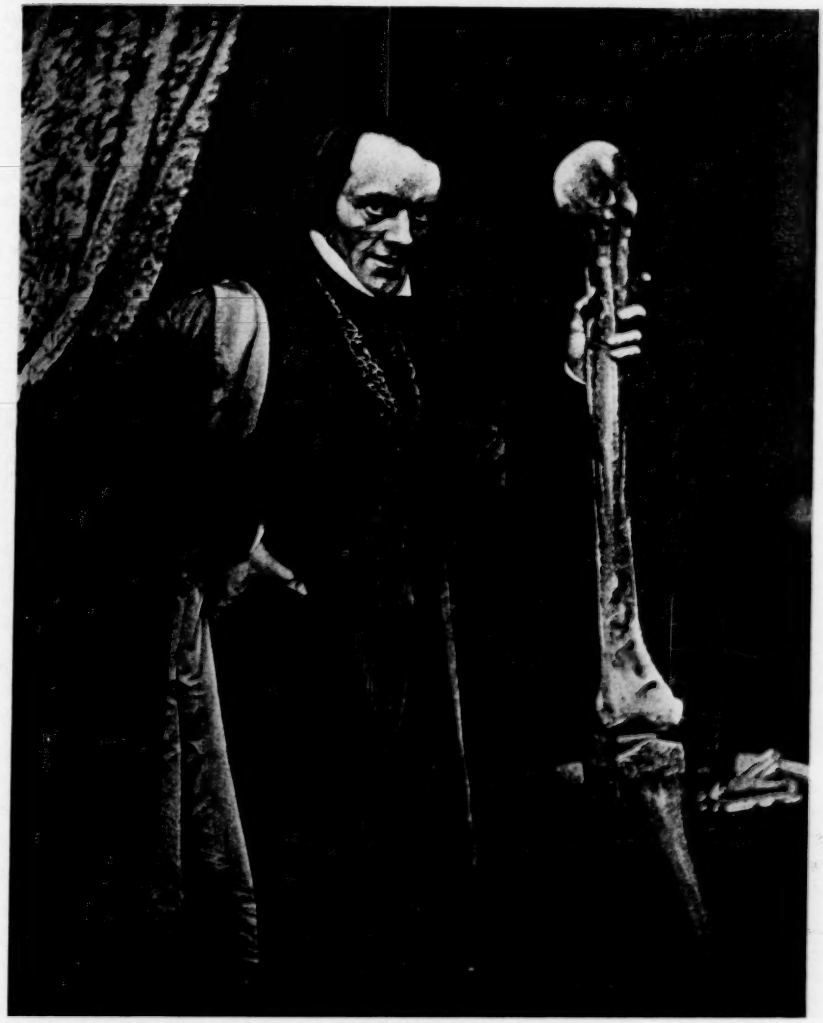

PLATE 1. A PORTRAIT OF OWEN TAKEN ABOUT THE YEAR 1846, AT THE TIME OF THE APPEARANCE OF HIS FIRST EXTENDED DISCUSSION OF THE GENERAL NATURE OF HOMOLOGY

Reproduced with permission from *The Life of Richard Owen*, by the Rev. Richard Owen, his grandson. *New York*, D. Appleton & Co., 1894.

When two or more parts or organs correspond with each other in structure, relative position, and mode of origin, we say that they are homologous parts, or *homologues;* whilst parts which have the same function, but do not correspond in structure, relative position, and mode of origin, are analogous parts or *analogues*. Homologous parts have therefore a morphological identity with each other whilst analogous parts have a physiological agreement. The same parts may be both homologous and analogous as the forelimbs of a bat and a bird, both of which with the same fundamental type of structure, are subservient to flight. In other cases analogous parts are not homologues, as is illustrated by the wing of the insect, which, though subservient to flight, is fundamentally different in structure from the wing of the bat or bird.

In brief, Turner says that organs which correspond in structure are homologous and those which do not correspond in structure are analogous, and then he proceeds to say that the same organs can be both homologous and analogous! Turner must have been a loose thinker—he used the term "morphological identity" when he meant morphological correspondence. Identity properly implies absolute resemblance or no difference. When an outstanding anatomist cannot keep the relation between the two most important terms in his whole treatise clear in his own mind, using his own definitions, within the space of a single paragraph—what about the reader? Surely there is something wrong in the terms themselves, if they become confused so easily. Owen did better than that. His meanings were relatively clear and consistent, and if they had been more widely adopted comparative zoology could have made more rapid progress. But how did Owen use the terms homology and analogy, and what, briefly, has been their historical treatment?

THE MEANINGS AND INTERRELATIONS OF HOMOLOGY AND ANALOGY AND A BRIEF ACCOUNT OF THE HISTORY OF THESE TERMS

According to Owen (1846, 1848, 1866) the term "homologue" had been in use prior to 1843 but "vaguely or wrongly". Owen refers to Geoffroy Saint-Hilaire (1825) who speaks of the term as being in use in *la philosophie Allemande*. If the writings of Oken may be used as an example of the German philosophy referred to (*Naturphilosophie*) we may readily agree that the term homologue would be used vaguely or wrongly, for such writings were more fanciful than philosophical and more philosophy than nature. Huxley (1894) stated that the term was well known and was in use even in its "present" sense as far back as 1800, but the recent German writers on the subject of homology (Spemann, 1915; Jacobshagen, 1925; Naef, 1926, 1927) all give Owen credit for the "introduction" of the term, meaning no doubt that he was chiefly responsible for placing it in the general consciousness of zoologists. Lankester (1899) praised Owen for giving "precision and currency" to the terms homology and analogy and stated that "It is not easy to exaggerate the service rendered by Owen to the study of zoology by the introduction of this apparently small piece of verbal mechanism: it takes place with the classificatory terms of Linnaeus." Owen, himself, took no credit for the *introduction* of the words.

Owen's 1843 definition of homology is of course incomplete; we need a statement of the criteria indicating what constitutes the quality of "sameness" in different organs. The quotations given below indicate clearly what these additional criteria were.

> These relationships [that is, homologies] are mainly, if not wholly, determined by the relative position and connection of the parts, and may exist independently of form, proportion, substance, function, and similarity of development. (1848, p. 6.)
>
> 'Homological anatomy' seeks in the characters of an organ and part those, chiefly of relative position and connections, that guide to a conclusion manifested by applying the *same name* to such part or organ, so far as the determination of the namesakeism or homology has been carried out in the animal kingdom. This aim of anatomy concerns itself little, if at all, with function. . . . (1866, p. vii.)

Here is probably the germ of Owen's genius, to realize that structural and functional resemblances are different qualities, different *kinds* of agreement, and should be clearly recognized as such. This brings us to Owen's use of analogy, and the interrelation of the terms homology and analogy to each other.

The 1843 definition of analogue was clear and reasonably adequate. It contained no prerequisites regarding structure.

> An analogue is a part or organ in one animal which has the same function as another part or organ in a different animal. (1843.)
>
> But homologous parts may be, and often are, also analogous parts in a fuller sense, viz., as performing the same functions: thus the fin or pectoral limb of a

porpoise is homologous with that of a fish, inasmuch as it is composed of the same or answerable parts: and they are the analogues of each other, inasmuch as they have the same relation of subserviency to swimming. (1848, p. 7.)

The hard parts of the leg of a crab or an insect may be 'analogous' to the bones of the limb of a quadruped, but they are not 'homologous' with them. (1849, p. 5.)

In the *Draco volans* [flying dragon or lizard] the forelimbs are 'homologous' with the wings of the bird; the parachute is 'analogous' to them. (1866, p. xii.)

These quotations show that Owen distinguished two chief kinds of resemblance in the corresponding organs or parts of the bodies of different animals: (1) essential structural agreements relating particularly to relative position and connections; (2) similarities in the function or use to the organism. These are really different qualities and they have no necessary dependency upon each other. Corresponding organs are either essentially similar in structure or they are not essentially similar in structure; they are used for the same purpose or they are not used for the same purpose, and there could be any combination of these pairs of alternatives as implied in their definitions, as shown below.

Analogous—similar in function or use
Non-analogous—not similar in function or use
Homologous—essentially similar in structure and relative position
Non-homologous—not essentially similar in structure and relative position

	Homologous	*Non-homologous*
Analogous	Forelimb of man and monkey	Forelimb of man Cheliped of crayfish
Non-analogous	Forelimb of man Wing of bird	Forelimb of man Gill of crayfish

The above meanings and relations of the terms become as clear as it is possible to make them, and their biological significance may likewise come to be understood as never before.

Now it is true that we use the term special homology today essentially as Owen used it. It is even true that Owen (1866) attributed the existence of special homologies to heredity. Skeptic as he was, Owen maintained that Darwin's and Lamarck's theories were "guess-endeavors", "conceptions of what may have, not observations of what have, originated a species." In the case of Lamarck's theory at least, Owen's skepticism was surely justified, and we should have been far ahead of our present understanding of the meaning of homologies and analogies if we had adopted Owen's meaning of analogy instead of the current meaning which implies a superficial similarity in structure associated with or "due to" a similar use.

Briefly the history of the use of the term analogy is as follows. Aristotle used the term to signify a similarity in use of parts or organs. If there were no such similarity in use the parts could not be analogues. Thus he says: "... we may consider the prickles of the hedgehog and porcupine as analogous to the hair of animals: for they answer the purpose of hair, ..." (*Historia Animalium*, Book I, Chap. 6). Again he states that "some animals agree with each other in their parts neither in form, nor in excess and defect but have *only* [italics mine], an analogous likeness, such as a bone bears to a spine, a nail to a hoof, a hand to a crab's claw, the scale of a fish to the feather of a bird, for that which is a feather in the birds is a scale in the fish" (*Historia Animalium*, Book I, Chap. 1). The above second quotation shows that Aristotle probably did not recognize all the more distant homologies (nail and hoof, scale and feather) but it seems clear that he was using the term analogy to imply a similarity in *function* and that he meant to give examples which have *only* an analogous likeness. As far as these statements go they appear to me to indicate that Aristotle used the term analogy as Owen did later to apply to organs which were similarly used whether they had an essential similarity in structure or not. It is unwise, however, to deny the possibility that Aristotle always meant to restrict the term analogy to organs which have but a superficial similarity in structure even though he did not succeed in doing so.

Taking a long jump now to the 19th century we find that the English zoologists were using analogy as our current texts mostly do—to indicate a similarity in use of organs which must be *only superficially similar in structure*. MacLeay (1825) gives himself the credit for the discovery which he made in 1819, that there were two kinds of structural agreements in animals, viz. those which show *affinity* (no genetic implication of common ancestry) by differing on a gradual scale by excess or defect, and those showing "analogy". According to MacLeay a relation of analogy consists in a correspondence between certain parts of the

organization of two animals which differ in their general structure. Here clearly analogy implies no more than a superficial similarity in structure: in other words, this is the opposite of homology as far as structure is concerned. These writers, MacLeay (1825), Kirby (1825), and others, used the contrasting terms affinity and analogy, the former roughly equivalent to special homology, except that there were no genetic implications, the latter to imply a superficial similarity in structure.

So far we have had two uses of analogy. The later English writers, Strickland (1846), Darwin (1859), and others, combined these uses and gained a strange chimaera so that we now have the term analogy defined as, "That [superficial] resemblance of structures which depends upon similarity of function as in the wings of insects and birds. Such structures are said to be analogous, and to be analogues of each other" (Darwin (1859, Glossary to the 6th edition—1920)). Darwin often speaks of "analogical or adaptive" structures, which showed only a superficial structural similarity—a curious statement for him to make, for it implies that only superficial similarities could be adaptive. But this is not the only way in which Darwin used the term analogy for he discussed briefly in all editions of the *Origin of Species*, the occurrence of "analogous variations" in related species and varieties of plants and animals, meaning the capacity of related species, which possess essentially similar genetic constitutions, to show the same type of hereditary variations. In this application the term analogy refers to organs and parts which are not only specially homologous but almost identical. Vavilov (1922) has discussed the same phenomenon and has referred to it as the "law of homologous series in variation"—a more fitting use of words. This unfortunate ambiguity of terms and ideas has led to endless misunderstanding. The confusion in terms has not been helped any by other writers besides Turner. Thus Hogben (*Encyclopedia Britannica*, 14th ed., 1937, article *Homology*) specificly attributes the current English chimaerical usage of analogy to Owen and thus makes a clear error of fact. Tait (1928) claims that Owen's term analogue did have structural implications, i.e. to imply a superficial similarity of structure. This again is proved false by Owen's own words quoted above.

It may be said of Lamarck, "The evil that men do lives after them; the good is oft interred with their bones," for it seems to be true that the mental association of common use for organs with a superficial similarity in structure was emphasized by these 19th century naturalists beyond all reason, even to the point of making them blind to the patent fact that most organs which have *essential* similarity in structure also are used for the same purpose and function in the same manner. The fact is, that organs may have the same use whether they are essentially similar in structure or essentially different, and, therefore, the common use can have no important relation to either condition. The cases where a common use has "made" organs superficially similar, such as the vertebrate and insect wings, were considered to be so important that they were given their own term "analogy" and were considered as a proof of the potency of environmental or functional factors in shaping organic structures, whereas actually they are a far better proof of the impotence of use in causing any *essential* change in structural organization.

But this is not all. Owen complained that the 19th century French zoologists commonly used the term analogue as practically equivalent to our modern homologue, i.e. to indicate essential morphological correspondence. Thus Geoffroy Saint-Hilaire wrote (1825, p. 341), "Les organes des sens sont *homologues*, comme s'exprimerait la Philosophie allemande, c'est-a-dire, qu'ils sont analogues dans leur mode de developpement. . . ."

Earlier (1818, p. xxxii) Geoffroy Saint-Hilaire had stated his "theory of analogues" which claims that the bodies of organisms are composed of corresponding organic materials. To quote. ". . . nous trouverons, dans chaque famille, tous les materiaux organiques que nous aurons aperçus dans une autre, est ce que j'ai embrassé dans le cours de mon ouvrage sous la désignation de *Theorie des analogues*".

There should be no further need of discussion regarding the necessity of clarifying the meaning of the terms homology and analogy. It must be clear to everyone that we have abused them and that we must use them more effectively in the future if comparative zoology is ever to acquire a sound basis. To remedy this situation Lankester (1870) proposed new terms (homogeny and homoplasy), but new terms are not indicated here. There is one bright spot in this story of words and ideas—Owen, who defined the terms clearly and used them effectively. I challenge anyone to misunderstand Owen's essential meanings if only he reads his words. The corresponding organs of

different animals are either essentially similar in structure and relative position (homologous) or they are not; the same organs are either used for the same function (analogous) or not; the concepts involved are absolutely clear and do not make any false claims that any kind of similarity in structure is "due to" use. Furthermore, in Owen's meanings we avoid all the misunderstanding that has come from the attempt to make analogy opposite in meaning to homology for it can never serve effectively in this capacity. If analogous meant only a superficial similarity in structure it could serve as the opposite of homologous but even for this purpose it can never be as effective as the plain term *non-homologous*. But when analogy has so often been used to mean a superficial similarity in structure associated with a similarity in use it must be obvious that it has no right to be used as the antithesis of homology. Is a similarity in use the opposite of an essential similarity in structure? Certainly not!

It would be further helpful if when we used the term homology by itself we meant only special homology, i.e. an essential similarity in the structure and development and in the relative position and connections of the corresponding parts of the bodies of *different* organisms. When the structural similarity in a series of appendages along the chief axis of the body is referred to we should use the term *serial homology* or, if a single word is preferable, *homotypy*. The latter term introduced by Owen (1846) was used in a different sense by Bronn in 1858, i.e. to refer to the similarity of the members of each pair of organs in a bilateral animal or to the larger number of corresponding organs circularly arranged in a radial organism. This is another illustration of the human capacity to confuse with words. Owen seems to have had a clear precedence in regard to the use and meaning of homotypy, and, in the absence of some good reasons for adopting that term with a very different meaning, Owen's usage should have been followed. Terms *are* the tools of the teacher as Owen said, and we should not continually use terms for purposes for which they are neither intended nor adapted. Just one more illustration of the abuse of terms: "homologous" in serology (50 years after Owen) was given a meaning which has no relation whatever to its meaning in anatomy.

The one thing that homology has always meant to a zoologist is morphological correspondence; the one meaning held the longest, and most commonly implied, in the term analogy is a similarity in use. Let us, therefore, keep these meanings and divest these terms of all other extraneous ideas. Let us return to Owen for if we do so we shall gain in the effective usage of homology and analogy and ultimately in the understanding of their implications for comparative zoology.

THE MECHANISM OF SPECIAL AND SERIAL HOMOLOGY

The mechanism of homology is the mechanism of heredity. By heredity we mean the transmission from parent to offspring of organized protoplasm with all its innate capacities. This mechanism is complex for its material basis is protoplasm of two chief kinds, viz. nucleoplasm and cytoplasm. Each of these chief components is composite; the former consisting of chromosomes with their contained genes, the latter of the polarized cytoplasm of the egg which is also in many cases further differentiated, containing visibly localized regions, or imperceptible potentialities for developing into particular organs. The differentiation of the egg becomes increasingly great with the progress of development until finally the various organs and parts of the organism reach their final degree of character expression. Thus organs and parts which may be homotypic or specially homologous come into being.

The manner in which such organs and parts develop has been the object of study of embryologists for a long time and of geneticists in recent years. The former concerned themselves chiefly with the behavior of the cytoplasm and the nucleus as a whole, the latter with the identification of individual genes and chromosomes and their distribution among the offspring. Each was so engrossed in the fascinating details of his own sphere of knowledge that the bearing of the discoveries made by each on the nature of the mechanism of homology has been but faintly understood. Thus, as cited in my preliminary report (1935), Duerden (1923–1924) and Crew (1925), examining the question of homology from the genetic viewpoint, completely misunderstood the mechanism of homology and even went so far as to claim that genetic homology was a delusion. Thus both Duerden and Crew knew that related animals inherit the capacity to develop fundamentally similar structures and yet, because genes are supposed to suddenly mutate, they insisted that there could be no real genetic homology—feathers and scales could not be homologous for they *must be* de-

termined by different genes! Duerden well knew of the transition from scales to feathers on the leg of one ostrich but he still insisted that scales and feathers must have a totally different genetic basis!

The remarks of Duerden and of Crew seem to be the only reports on the genetic basis of homology made by geneticists up to recent times (Boyden, 1935) and those, as we have seen, were totally wrong. Homology *is* a genetic phenomenon, and, in the case of both special and serial homology, the mechanism is that of the orderly interaction of genes and cytoplasms with each other and with the environment. We cannot as yet state precisely in chemical terms what the entire chain of reactions is from beginning to end of the development of any homologous part or organ, but some of the links of the chain are being forged for us from the labors of both geneticists and embryologists. There is, in fact, sufficient information at hand to outline tentatively the mechanism of homology.

In brief it has been established that: (1) the protoplasmic continuity between successive generations of organisms includes a continuity of both (a) genes and (b) organized cytoplasm; (2) each gene generally has manifold effects on the body; (3) each complex organ is conditioned by the interaction of a large number of genes with each other and with the cytoplasm; (4) during development of the individual, the genes usually do not differentiate and are distributed equally to all cells, whereas the cytoplasm normally does differentiate and is not equally distributed to all cells; (5) the specific nature of homologous organs, and indeed of the entire individual, is determined primarily by inheritance.

Of these statements of essential truth, the fourth is perhaps more in need of direct experimental verification than the others. It is based on many facts of normal and experimental development and regeneration which prove the equal potentiality of large numbers of cells in the bodies of particular organisms. The mechanism of mitotic division, the occurrence of indeterminate cleavage, the existence of heteromorphic regenerative capacities, all support the statement. On the other hand, the occurrence of chromatin diminution in Ascarids and other groups of invertebrates is a kind of reservation to the statement, which, however, does not deny its general validity even for those organisms. The recent report of differences in the chemical compositions of the chromosomes of different organs of the body by Mirsky and Pollister (1943) may not be actual proof of genic differentiation but only of chromosomal differentiation in various cells. There are also cases of intra-individual gene mutations and abnormal somatic chromosome segregations, but these are not concerned with the normal development of homologues and homotypes in the great majority of cases. The great bulk of the evidence thus does support the statement of cytoplasmic differentiation during development along with nuclear and particularly genic non-differentiation, as suggested so long ago by Conklin.

Now with this general truth before us we are in a favorable position to describe what the basis of similarity and difference in homologous and homotypic organs may be in particular cases. Take for instance the comparison of homologous and homotypic appendages in *Drosophila* species.

The wings and halteres of *Drosophila* are generally considered to be "homologous", that is, serially homologous or homotypic. This interpretation is supported by the occurrence of such genic mutations as tetraptera (Astauroff, 1929) and tetraltera (Goldschmidt, 1940; Villee, 1942a). In the former the halteres are enlarged to wing-like expressions; in the latter the forewings are reduced to haltere-like expressions. In either case many transitional stages between the normal and extreme mutant expressions are found, showing that the genetic and embryological mechanism responsible for these two types of expression is subject to modification. A recent discussion by Villee (1942b) lists and discusses these and other cases of homoeosis, and they are discussed also from the standpoint of macro-evolution by Goldschmidt (1940).

Homotypic organs are fundamentally similar in structure yet they usually bear characteristic differences. Their resemblances may be due, then, to the same genes acting upon the similar (though organized and polarized) cytoplasm of one egg or one individual. The differences in homotypic organs would be due to the action of the same genes in all cells acting upon localized differences in the cytoplasms of one egg and its cellular descendants. Now there may be long series of similar homotypes as in the crayfish and lobster where the essential similarity of pereiopods and pleopods indicates an extended genic and cytoplasmic similarity in the regions from which these appendages develop. The facts of regeneration of these appendages

indicate that these cytoplasmic and genic conditions persist throughout life. On the other hand, there may be very great differences in the adjacent protoplasm within short distances, for the most diverse organs develop side by side and even in actual contact. Thus nerves, muscles, and bones develop in the most intimate connection. Indeed all the parts of a complex organism come from the same egg in the case of sexual reproduction. Obviously "genetic origin" alone does not define the condition of homology or of homotypy. Both conditions require an essential similarity in structure and some degree of correspondence in relative position.

The mechanism of special homology is based on both genes and cytoplasm, as in the case of homotypy, but with certain significant differences, viz. the correspondence of the wings of two individuals of the same or different species of *Drosophila* is due to the interaction of the same or similar genes reacting upon the similar cytoplasm of two eggs. The same general principles apply to both sexual and asexual reproduction, the chief differences between the two types of reproduction relating to (a) the size of the fragments of protoplasm forming the basis of the new individual, and (b) the application of the principles of Mendel and Morgan to the differential distribution of genes among offspring which may occur in sexual, but not in asexual, reproduction. Thus, because of the fact that each complex organ is dependent upon the interaction of large numbers of genes, the essential resemblances of specially homologous organs in different individuals are due to the interaction of large numbers of identical or similar alleles interacting with similar cytoplasms. The differences between special homologues would be due to the interactions of the same genes with different cytoplasms, or to different genes interacting with the same cytoplasm, or to differences in both. Generally we may say that of the two chief components of the material basis of heredity, the germ plasm, the cytoplasms are more conservative than the nucleoplasms. This statement is supported by the general principle that reciprocal crosses involving differences in the genotypes give similar results which could not be the result if the cytoplasms of the different eggs involved in the reciprocal crosses were different in respect to the particular characters compared. On the other hand, the occurrence of certain cases where reciprocal crosses give different results probably indicates a difference in the cytoplasms concerned.

Of the two, genes and cytoplasm, the latter is, therefore, apparently the more conservative. Speaking of conservatism, the relative degrees of hereditary persistence in position and connections in comparison with structure as guides to the homology of the developed organs must be examined. Which is more variable, the relative position or the structure of organs? We recall that Geoffroy Saint-Hilaire strongly emphasized relative position as the decisive criterion of special homology in organs. Thus he wrote (1818, p. xxx), ".....un organe est plutôt altéré, atrophié, anéanti, que transposé." (....an organ is more often altered, atrophied, eliminated, than transposed. Author's translation.)

Geoffroy Saint-Hilaire took an extreme stand regarding the value of relative position and connections in determining homology, and we cannot follow him that far. Owen was willing to admit that relative position was the most important criterion of special homology but he did not in practise admit homology unless there was also an essential structural similarity particularly in the adult stages of the organs compared. In this view he is supported by modern genetic knowledge. Thus it is definitely known that hundreds of gene mutations affect the structure of homologous organs to one that affects their relative position. Indeed, it is difficult to find cases, where the hereditary mechanism has been analyzed, where genes actually cause organs to occupy different positions in the body of the individual. Thus well over a hundred genes modify the structural expression of a *Drosophila* eye and none transposes it to a different part of the body! Nearly as many genes affect the structure of the wing but none transposes it even one segment anteriorly or posteriorly! The tetraptera gene effects the degree of development of the halteres *in situ* but does not cause the wings or halteres to change their relative position. The mutant tetraltera reduces the forewings to halteres again *in situ*. As long as any wings develop at all, their rudiments or modified structural expressions maintain the same relative position and connections. Geoffroy Saint-Hilaire was partly right and Owen was completely right in regarding relative position and connections as one of the most conservative criteria of special homology.

The question may properly be asked, therefore,

are there *any* cases known where genes do change the relative position of organs? Take the case of proboscipedia (Bridges and Dobzhansky, 1933). Here distal parts of the proboscis take on remarkably tarsus-like expressions. It would seem, at first sight, that here the genes have acted to move some of the tarsi to the mouth region, but actually this is not true. The fact is that the original tarsi still occupy their normal position on the legs. The proboscipedia gene then acts in some manner, such perhaps as that outlined by Goldschmidt (1940) or Villee (1942b), to change the expression of the appendages in position.

We need not deny that genes could cause a transposition of appendages in the body. Actually this appears to have happened in the evolution of certain fish where the pelvic fins are displaced forward. If proboscipedia should prove to have survival value and persist long enough to be followed by mutations which suppressed the development of leg tarsi in whole or in part, then we would have an apparent case of movement of organs resulting from gene action. It has recently been reported by Villee (1943) that the mutant "aristapedia" (Bridges) shows a variable expression of tarsus in place of part of the arista, associated with defects in the development of the leg tarsi. This is an exceedingly rare case, however, which does not gainsay the general conservatism of relative position and connections as criteria of special homology.

Now it is generally believed that the mouth parts and legs of Arthropoda are not only serially but specially homologous. Similarly wings and halteres are considered specially homologous if they correspond in relative position in the bodies of different individuals. Mutants of the type of tetraptera, tetraltera, and proboscipedia do not therefore cause changes in the special homology of the organs concerned. But in the case of aristapedia we may have something different in this regard, for there is no conclusive evidence known to me which proves that the antennae of Insects or any part of them have ever been specially homologous with legs, in other words, that these appendages have had a common phylogenetic origin. If antennae and legs have had no common evolutionary origin then aristapedia represents a real change in special homology, and this together with the few cases where eyes are partly converted into palpus-like organs (Goldschmidt, 1940) appear to constitute the only cases where we may conclude that there have been changes in special homology due to gene mutations in *Drosophila*. The very rarity of such occurrences indicates that the genetic mechanism is capable of maintaining for long periods of time those essential similarities of structure and of relative position which are the criteria of special homology, and which make it possible to interpret special homologies in terms of real genetic relationship, however distant.

We may stop for a moment here to attempt to answer the question, why are changes in special homology so rare? There is a partial answer available from modern genetic knowledge. In the first place, each organ depends upon the interactions of many genes with themselves and with the even more conservative cytoplasm so that changes in one or even many genes do not destroy the essential nature of the organic structures. It is here that Crew and Duerden went wrong—they appear to have visualized a one-to-one relation between gene and complex organ so that when the gene changed abruptly the organ was expected to change abruptly and lose its homology at one blow, so to speak. But we now know that the very complexity of the genic and cytoplasmic basis for organs guarantees conservative structural expressions so that in the case of the wing, if any wing develops at all, it is still essentially a wing and nothing else.

Furthermore, as we have seen, whatever form the wing may take, it still occupies the normal position of the wing. Why is relative position generally more conservative than structure? There are two obvious explanations which are not mutually exclusive: (1) either changes in genes affecting position are rare; or (2) the relative position of organs in the body is determined mainly by another mechanism, the cytoplasm itself. There is evidence that cytoplasms are more conservative than nucleoplasms, obtained from the general fact of equality of results in reciprocal crosses. May it not also be true that the relative position of organs in the body is *mainly* determined by the polarity of the cytoplasms which may have some dependence upon the nucleus as a whole but seldom upon particular genes? We do know of cases where genes affect the structure of the cytoplasm, as in the case of the direction of coiling in snail shells, but such cases are relatively rare. At any rate it is clear that homotypic differentiation is a phenomenon of cytoplasmic polarity and differentiation rather than of intraindividual gene differentiation.

If this is true it is to be expected that changes in relative position will be rare in evolutionary history. Furthermore, a change in the structure of an organ so great as to justify a conclusion that there has actually been a change in special homology will also be a rare event. The infrequencyof changes in relative position would be due principally to the primary dependence of position on the cytoplasm, the rarity of changes in special homology to the complexity and conservatism of the genic and cytoplasmic basis controlling the development of each organ.

We have thus outlined the mechanisms of serial and special homology. What can be gained by a comparison of homotypic and homologous series of organs? Compare for instance the homotypic series of appendages in a lobster and in a crab and then compare the corresponding appendages as homologues. Bear in mind that homotypes are intraindividual organs whereas homologues imply interindividual and, most often, interspecific comparisons. The former obviously have no direct bearing on the problems of special homology and genetic relationships, whereas the latter do. But is there any indirect bearing of the two series of comparisons on each other?

The most striking fact which appears from the comparisons of homotypes and homologues (Fig. 1) is that, generally, homotypes differ more than homologues! Thus the homotypes vary from antennules to uropods in the lobster, and from antennules to pleopods in the crab, and the differences are far greater than between any of the homologues of these homotypic appendages. The pereiopods of crab are far more like the pereiopods of the lobster than the pereiopods of either are like the pleopods of the *same individual*. And this appears to be generally true everywhere. This is a further remarkable illustration of the conservatism of homologues.

Another interesting fact which emerges from the comparison of homologues and homotypes is that, in spite of differences in the mechanisms of the two, there may be apparently similar results from the operation of the two kinds of mechanism. Thus adjacent homotypes of crab or of lobster may be chelate or non-chelate, such as the third compared with the fourth pereiopods of the lobster and the first compared with the second pereiopod of the crab. A similar difference may occur between homologues, such as the first pereiopods of the crab or lobster compared with the non-chelate first pereiopod of the spiny lobster (*Panulirus argus*). In accordance with our general interpretation we must go to a rather distant relative of the crab, or of the northern lobster, to the "spiny lobster," the species being separated by long periods of evolutionary divergence, in order to find as great a difference in homologues as we readily find in the homotypes of the same individual! These interesting parallelisms must be viewed with care, however, for the chief significance of special homology to the zoologist is as it guides to genetic relationship, whereas homotypic correspondences have no such significance. On the whole, therefore, comparative zoology will be best served by keeping the phenomenon of homotypy or serial homology distinct from special homology and by leaving no doubt in the minds of our readers as to which kind of correspondence is being discussed. This opinion can be maintained in spite of the fact that in some cases there may be a difference of opinion as to which kind of structural correspondence is really present. For example, take the case of any common tapeworm. Whether the corresponding organs of each proglottid are homologous or homotypic depends on whether one views the tapeworm as a colony or as a single individual. I incline toward the former interpretation which is supported on many grounds, including the fact that homologous organs are generally more similar in close relatives than homotypes are. This agrees with the view that the proglottides are really different individuals. However, this is a case where judgment plays an important part in the interpretation of zoological facts and illustrates how a certain interpretation finds support from an entirely different basis of analysis and thus leads to an intelligible view of these complex biological phenomena.

There is one more bearing of our outline of the mechanism of homology and of homotypy on the interpretation of biological data. This is the matter of heteromorphosis, the regeneration of a structure other than that removed or injured. There seems to be some idea among recent writers (Goldschmidt, 1940; Villee, 1942b) that homoeosis and heteromorphosis are synonyms, but this is not the case. Homoeosis refers to the substitution of homotypes or serial homologues for each other, whereas heteromorphosis means the replacement of one organ by any other which need not be homotypic. It has commonly been assumed that the regeneration of an antenna-like organ in place

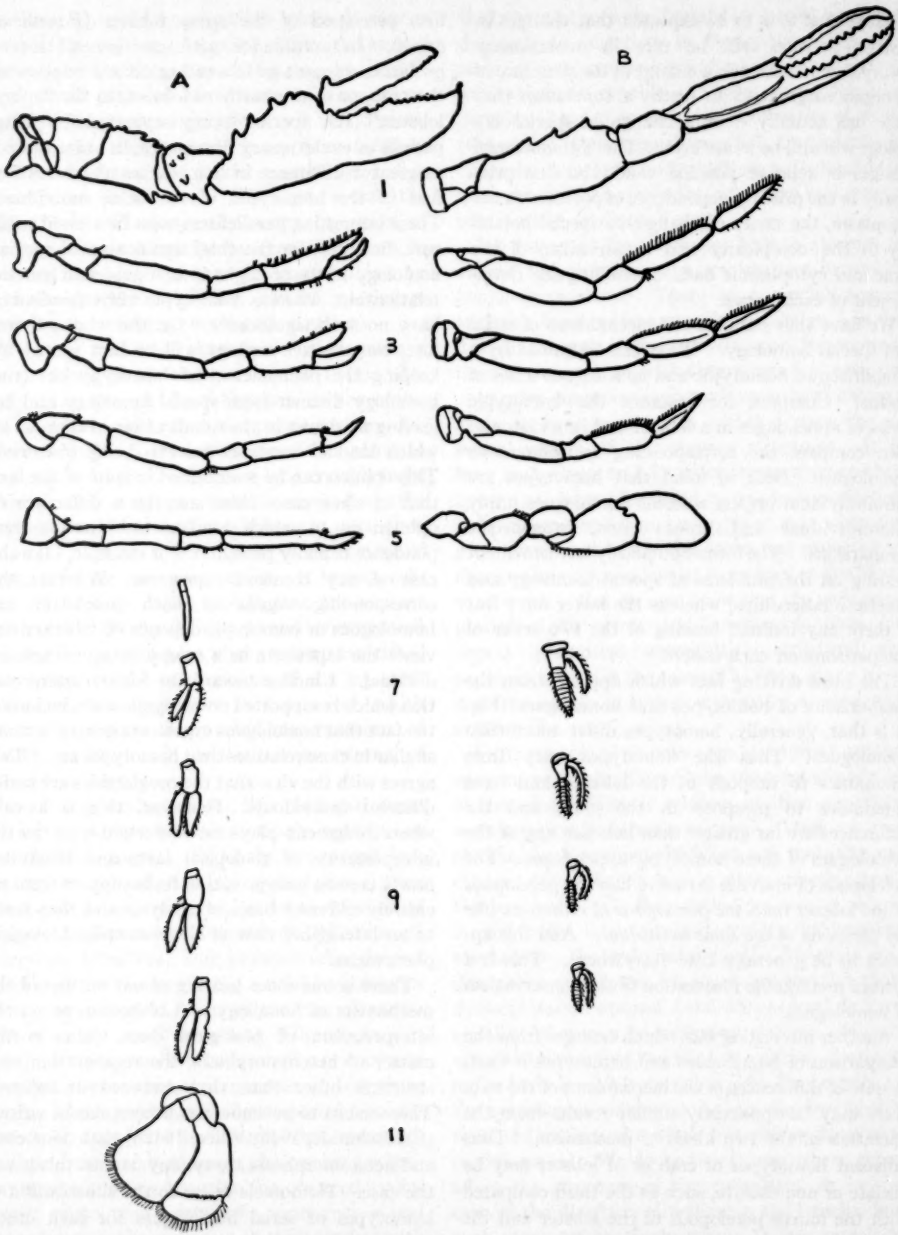

FIG. 1. DRAWINGS OF A SERIES OF HOMOTYPIC APPENDAGES OF A, THE LOBSTER HOMARUS AMERICANUS, AND B, THE BLUE CRAB CALLINECTES SAPIDUS (BOTH FEMALES)

The pereiopods are numbered from 1 to 5 inclusive, the chelipeds being considered as first pereiopods. The pleopods are numbered from 6 to 10 inclusive, the first pair being absent from the female crab. The uropods, number 11, are also absent from the crab.

of an eye in certain Crustacea (Herbst and others) is a proof of the homology of the two expressions. It is true that each organ in succession occupies the same relative position in the body, but we cannot maintain that relative position alone proves the homology. There must be an essential structural resemblance in the organs which are homologous, otherwise homology loses all significance for comparative zoology. We have seen that the differentiation of homotypes is due to cytoplasmic differences and not gene differences, and it is obvious that the cytoplasm of one shrimp egg can, interacting with the cellular genotype, develop into either an eye or an antenna. Surely no zoologist would maintain, however, that all the organs which develop from one crustacean egg are homologous. No more can one maintain that the regeneration of antenna in place of eye is proof that they are homologous regardless of their essential structural differences. Furthermore, there is no more evidence of special homology between the eyes and the antennae in Arthropod ancestry than for the special homology of antennae and legs. Calman (1909, p. 10) was, and still is (recent correspondence), unconvinced of the serial or special homology of the eye with any other crustacean appendage.

The process of regeneration may be considered as a kind of embryologic one, and there remains but to discuss briefly the bearing of developmental similarity on the determination of special homologies. Owen considered that identity of development was not required to establish the condition of special homology though he admitted "There exists doubtless a close general resemblance in the mode of development of homologous parts; but this is subject to modification, like the forms, proportions, functions and very substance of such parts, without their essential homological relationships being thereby obliterated" (1848, p. 6). In other words, Owen considered the definitive adult structural expression and relative position as being the decisive criteria of homology. In this he has been supported by Wilson (1896) and others. I think again that Owen's views are sound and that if there is essentially similar adult structure and relative position the organs are homologous, whether they come from the same or different "germ layers" or show other minor developmental differences. After all, the different germ layers of a single individual do have the same genes, and whether the lens of a newt comes from ectoderm or mesoderm, or the pharynx of an earthworm from entoderm or ectoderm, is, in my opinion, a matter of local significance only.

ADDITIONAL CRITERIA OF HOMOLOGY; GENES; SEROLOGICAL CORRESPONDENCES

Homology in genes is demonstrated directly by the test of allelism and such tests are of prime importance as guides to genetic relationship not only of the genes themselves but of the bodies of two individuals possessing such alleles together with all their corresponding parts. We might imply that the final proof of special homology in organs was the proof of the allelism of the genes concerned. Unfortunately, the test of allelism requires crossing with the production of at least one generation of hybrid progeny, and such hybrids are obtainable only from fairly closely related animals and plants. This test is of too short a range, therefore, to bring us to the limit of the relation of homology. The fact is that, at present, the endpoint of this relation is indefinite and depends upon what constitutes "essential structural similarity." There is a recent tendency (Jacobshagen and others) to limit homology to organisms belonging to the same "type" and not to extend the relationship to all organs bearing some degrees of structural similarity, such as the enterons of round worms, segmented worms, arthropods, and chordates. There *is* a definite need for some independent criterion of homology which can serve to indicate its endpoints, and thus settle some old problems of phylogeny and genetic relationship. It is just possible that serology can do this (Boyden, 1942) indicating, as it does, the varying degrees of antigenic correspondence in the circulating fluids or organs of the bodies of related organisms. Thus Wilhelmi (1942) has obtained evidence of greater serological resemblance between Echinodermata and Prochordata than between Annelida or Arthropoda and Chordata, and Eisenbrandt (1938) has reported evidence of a greater similarity of Acanthocephala to Platyhelminthes than to the Nemathelminthes with which they are usually classified. If these findings are firmly established they provide additional evidence of a real genetic relationship of the organisms mentioned. Thus they would validate the interpretation of homology in the corresponding organs of organisms included in the related phyla. Much depends upon future investigations in such cases.

Here we are then, a hundred years since Owen's first definitions of analogue and homologue. His definitions and his applications were for the most part and clear and effective. But we have been slow to follow. We have abused the terms and misinterpreted their meanings, and it is time to try to resume the forward march along the main route of comparative anatomy begun by Owen. I strongly recommend that we consider carefully Owen's essential meanings of homology and analogy and that, if his interpretations and applications are as clear and effective as they are represented to be in this discussion, we adopt his meanings at once. One hundred years is surely long enough to "try all things," and to use those words in so many different ways. The time has come to "hold fast to that which is good."

SUMMARY

The terms homology and analogy, as used at present, lack that precision and clarity of meaning which is essential to their effective application in comparative zoology. Owen, one hundred years ago, used these terms effectively, and it is recommended that we adopt Owen's meanings without further delay. Homology is a genetic phenomenon and both serial and special homology are based upon mechanisms which involve the interaction of genes and cytoplasm, but serial homology or homotypy (Owen's meaning) has no direct bearing upon problems of genetic relationship, whereas special homology bears directly upon the analysis of racial descent. The genetic mechanism of special homology is such as to ensure that both the relative position and essential structure of complex organs will be transmitted for many successive generations—hence modern genetic knowledge affirms the validity of these criteria of special homology. There remains for the future the task of developing some objective endpoint for the condition of special homology which can truly indicate the more remote genetic relationships.

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THE BIOGEOCHEMISTRY OF ALUMINUM AND OF CERTAIN RELATED ELEMENTS (*Continued*)

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THE ALUMINUM CONTENT OF ANIMALS

TURNING to the animal kingdom, we find far less data available than for plants. No well established cases of aluminum accumulation are known, and in general the element, though probably constantly present, is less abundant than in plants.

Aluminum in the Invertebrates

Among the Protozoa there is indeed one record that, if acceptable, would indicate the production of a skeleton containing aluminum. Schewiakoff (1902) published an analysis of the skeletons of free-floating Acantharian Radiolaria from the Mediterranean; this skeletal material, derived from a number of genera mixed together, was said to consist of SiO_2 21.6 per cent, $(Al, Fe)_2O_3$ 17.6 per cent, CaO 31.4 per cent, and undetermined material 29.4 per cent. The sesquioxide precipitate was very pale, so that Schewiakoff considered that it was primarily alumina, and concluded that the skeleton was largely a calcium alumino-silicate. Working with *Podactinelius sessilis* Ol. Schr., a stalked form referred to the Acantharia, Bütschli (1906, 1907) found about 5.5 per cent SiO_2, which he suspected was derived from contaminating fragments of sponge spicules, much sulphate, and a small amount of iron but no aluminum. The major metallic constituent was an alkaline earth element, comprising about 29 per cent of the skeleton; qualitative tests on the original material strongly indicated this element to be strontium, so that the principal substance present is apparently strontium sulphate. Though no spectrographic test has ever been made, the identification is reasonably certain. Bütschli performed a few tests on Mediterranean planktonic forms and believed strontium to be present in their skeletons also, though in these organisms the evidence is far less certain than in *Podactinelius*. He points out that if the supposed calcium of Schewiakoff's analyses were really strontium, present as sulphate, the latter radicle would account for 24 per cent of the 29.4 per cent loss recorded by Schewiakoff. Schewiakoff (1926) returned to the matter in his monograph of the Acantharia, but was not able to give any new data. On morphological grounds, however, he excluded *Podactinelius* from the Acantharia, and so considered that the composition of its skeleton was irrelevant to that of the skeletal structures of the true members of the group. He therefore provisionally adhered to his previous conclusion. Schewiakoff's determination of his supposed sesquioxide precipitate as mainly aluminum is, however, quite unreliable; if any appreciable amount of ferric phosphate were present the pale color would be produced in the absence of aluminum. Bütschli's explanation of the considerable undetermined fraction is tempting, but further discussion of this supposed alumino-silicate skeleton is futile until more analytical data are forthcoming.

Among the metazoan marine invertebrates there is little information. Webb (1937) who has made the most extensive study of the problem, found aluminum in nine out of twenty-nine tissues analyzed, but he clearly regards the presence of the element in whole animals or in parts, such as the branchial sac of *Ascidiella*, which are easily contaminated, as of little significance. He considers that in general the aluminum content of benthic marine animals is below the limits of sensitivity of his spectrographic method, i.e. below 0.03 per cent of the cations or about 6 milligrams per kilo. of living tissue. Since in two presumably uncontaminated tissues, the chelar muscle of *Eupagurus bernhardus* and the ovary of *Paracentrotus lividus*, aluminum was definitely present, constituting 0.08 per cent of the cations, or about 16 mg. per kilo. of living tissue, it is probable that the mean amount of aluminum is not much below the

smallest amount that Webb was able to detect. Meunier (1936) found that the muscle of *Maia* and *Octopus* contained 8 and 11 milligrams per kilo. of dry matter respectively; this would correspond to 1 to 3 milligrams per kilo. of living tissue, but as the muscles of mammalia are notably deficient compared with the viscera, it is not improbable that in these forms also the mean amount may be a little higher. It would therefore appear that for the entire range of benthic invertebrates the mean aluminum content is of the order of $n \times 10^{-4}$ per cent, where n is not unlikely to lie between 2 and 6. Both Goldschmidt (1937) and Haendler and Thompson (1939) find that the average concentration of aluminum in sea water is approximately $5 \times$ or 6×10^{-5} per cent. It would thus seem that even if the aluminum in marine animals were entirely derived from the soluble aluminum of the medium, the mean concentration factor cannot exceed 10. However, since the first section of this review was in print, a paper by Wattenberg (1943), reviewing the trace element content of sea water has appeared, in which unpublished determinations of aluminum by K. Kalle are quoted. Kalle finds but 0.120–0.135 mg. per litre in ocean water, and but 0.07–0.08 mg. per litre in the Baltic. Such values imply a concentration factor five to ten times greater.

Ranzi (1939), in his study of the changes in the concentrations of the rarer metallic constituents in the developing egg of *Sepia officinalis*, has given some interesting data on aluminum. Two series of analyses are presented, one for isolated ova developing into embryos with their vitelline sacs (termed *embryo* below), the other for the whole of the egg with its massive covering (termed *egg* below). Though these data are based on different series, a rough idea of the changes in the egg membranes can be obtained by subtraction. The net weight of the embryo increases by 30 per cent during development; most of this increase is due to intake of water. The extremely small ash content of the embryo is also approximately doubled during development, mainly due to the intake of calcium. The organic matter of the embryo naturally decreases. The much more massive membranes take up large amounts of water and ash, both constituents being increased approximately fourfold during development. The data are not sufficiently extensive to reveal any systematic variation in the organic content. The newly deposited egg contains 0.6 γ Al, apparently all present in the embryo. During development 0.5 γ Al are taken up by the embryo, and 2.7 γ by the membranes. The relative quantities present are as follows:

		Wet mg. per kilo.	*Dry* mg. per kilo.	*Ash* mg. per kilo.
Embryo:	initial.....	9	20	700
	final.....	13	46	600
Membranes:	initial.....	0	0	0
	final.....	1.9	25	52
Egg:	initial.....	1.4	10	50
	final.....	2.6	35	70

While it is obviously difficult to compare either a relatively dry embryo with little ash, or egg membranes, with adult organisms, the figures given in the first column do not conflict with what has been presented as to the aluminum content of marine metazoa in the preceding paragraphs.

The high initial aluminum content, relative to the exceedingly low ash content of the ovum, is interesting. The tendency for the element to be fixed in the ovum is maintained in the developing embryo, for the ash entering the embryo contains 590 mg. per kilo. Al, while that entering the membranes, and remaining there, only 68 mg. per kilo. In spite of the absolute increase being greater in the membranes, the relative increase thus appears greatly in favor of the egg. If the other elements are examined in the same way, we find that although, save in the case of copper, the absolute increase is always greater outside the embryo, the increase relative to the uptake of ash is greater in the embryo for all the minor constituents save barium. Thus 15.6 per cent of the aluminum entering the egg passes into the embryo, and in this respect the element occupies a position between potassium (10 per cent), vanadium (11.3 per cent) and iron (13.3 per cent) on the one hand, and strontium (16.6 per cent), nickel (20 per cent), zinc (29.2 per cent), and manganese (30 per cent) on the other. The absolute increment for either embryo or egg is, however, less for aluminum than for any of the other elements studied by Ranzi, save nickel and beryllium. For the whole egg, adopting 0.6 mg. per litre as the aluminum content of sea water, the need could be supplied by 5.3 millilitres. This contrasts most strikingly with the 21 litres needed to account for the nickel increment, or the 500 litres for that of vanadium. We may conclude that if the embryo requires aluminum, the very unequal partitioning initially present ensures it a good supply, that the element

is taken up in very small quantities by the whole egg, and that although only 15.6 per cent of the intake goes into the embryo, such a percentage is comparable to those found for other metabolically more important elements. It is, however, impossible to conclude from Ranzi's data whether aluminum is likely to play an active part in the biochemistry of the *Sepia* egg. The data subsequently to be presented on the succinoxidase system suggest, however, that here, as elsewhere, some functional rôle is probable.

A single supposed case of concentration of aluminum by a marine metazoan has been reported. Schütze (1889) investigating the cellulose of the mantle of the tunicate *Phallusia mammillaris*, analyzed that fraction of the ash of the ether-extracted mantle that was not soluble in hot water. Since his paper is rather inaccessible and has apparently been mentioned by more writers than have consulted the original, the full analysis of this ash is given, recalculated as oxides.

	Per cent
SiO_2	2.76
Al_2O_3	9.52
Fe_2O_3	15.81
CaO	29.70
MgO	2.88
P_2O_5	14.52
CO_2	24.81

In view of the treatment to which the material had been subjected, the carbon dioxide of the analysis, probably determined by difference, can have little meaning. It is very improbable that such material, low in silica and high in iron, could be mainly derived from contaminant sediments; on the other hand, it may well represent colloidal material precipitated from sea water onto the cellulose of the test and so hardly a part of the organism. The material has some resemblance in composition to the acid-insoluble fraction of certain phosphatic nodules. It is most unfortunate that there is no indication of the quantity of this ash present in the mantle, but it presumably represents but a small part of the total mineral constituents. A further investigation would undoubtedly be of interest. Two other reports for the tunicates are available. Meunier records 80–140 mg. per kilo. of dry matter in *Ascidia mentula*, from which the gut had been removed. This would correspond to about 0.04–0.05 per cent Al_2O_3 in the ash. Webb similarly records 0.2 per cent Al in the cations of the branchial sac of *Ascidiella aspersa*, corresponding to about 0.16 per cent Al_2O_3 in the ash. Both figures are much higher than those given for other marine animals, but Webb attaches no great significance to his record, clearly regarding it as due to contamination.

Turning to non-marine invertebrates, there are a few records of no great importance. Flury (1912) records 2.637 per cent of the ash, 0.131 per cent of the dry matter, or 0.0197 per cent of the living tissues of *Ascaris lumbricoides* to be aluminum. This quantity is in excess, not only of the iron, but also of the magnesium content. Since the determination was made by difference and no precautions were taken to prevent the precipitation of alkaline earths in the presence of excess phosphate (PO_4 26.131 per cent of ash), no great significance can be attached to the aluminum analysis, which is given without comment. Accumulation of aluminum phosphate in, or on, this parasitic worm, while just possible, is certainly not established. The figures given by Vinogradov (1935b) from analyses by Kudovets of *Potamobius fluviatilis* show a curious sexual dimorphism not strikingly exhibited by any other element; the male is said to contain 0.033 per cent Al in the dry matter and the female 0.20 per cent. For this reason alone these data are to be regarded as suspicious. The supposed occurrence of aluminum in the Coccidae has already been mentioned. Aronssohn (1911) found 0.01 per cent Al in the dry matter or 0.24 per cent in the ash of the ♂ honeybee; qualitative spectrographic indications of aluminum in the cockroach, *Blatella germanica* (L.), have also been given (Haber, 1926).

Aluminum in the vertebrates

Among the contributions concerning the aluminum content of the vertebrates, the majority, as might be expected, relate to the mammalia. Staffel (1851) found traces of the element in veal, and Söldner and Camerer (1903) no less than 16 mg. per kilo. fresh weight in the human neonatus, but practically all the available data are very recent. Berg (1913) noted aluminum in some specimens of mammalian meat, the amount exceptionally reaching 0.0025 per cent of the wet weight. Little attention need be paid to the work of Gonnerman (1918a) who, like Stoklasa (1922), supposedly found the element in the feathers of certain birds, and later (1918b) reported relatively enormous quantities, up to 29 per cent Al_2O_3 in the ash of the

TABLE I

Aluminum content of Mammalia

(mg. per kilo. fresh tissue)

TISSUE	RATTUS NORVEGICUS		CANIS FAMILIARIS		HOMO SAPIENS	
	Normal diet	Low Al diet	Myers and Morrison 1928	Eveleth and Myers 1936b	Myers and Mull, 1928b	Kehoe, Cholak, and Story, 1940a
	Myers and Mull, 1928a					
Brain	0.0–0.9 *0.5*	2.0	—	1.0–3.7 *1.9*	0.7–4.5 *2.5*	*0.04*
Liver	0.9–2.9 *1.4*	0.3–1.3 *0.8*	0.8–3.7	0.9–1.9 *1.4*	0.5–1.4 *0.8*	*1.6*
Tongue	0.9–2.9 *1.6*	*0.8*	—	—	—	
Heart			0.2–1.7 *1.1*	0.6–3.8 *1.1*	1.1–2.9 *2.1*	*0.56*
Thyroid	1.8	—	—	—	—	
Kidney	1.5 (with adrenal)	0.7	0.3–1.4 *0.8*	0.3–1.2 *0.7*	0.2–3.4 *1.0*	*0.42*
Spleen	2.9		0.3–1.4 *0.7*	0.5–1.4 *0.8*	0.3–1.3 *0.7*	*1.30*
Lung	0.0–1.3 *0.6*	0.9	—	0.9–3.5 *1.7*	—	*59.4*
Gall-bladder and bile	—	—	—	2.1–4.0 *2.8*	0.1–1.7 *0.7*	—
Pancreas	—	—	—	0.4–0.8 *0.6*	—	—
Stomach	—	—	—	0.2–2.0 *1.0*	—	*0.73*
Intestine	—	—	—	0.1–3.3 *2.0*	—	*0.87*
Blood	0.5–0.7 *0.6*	0.2	—	0.0–0.2 *0.1*	—	*0.15–0.13*
Muscle	—	—	—	0.0–0.5 *0.3*	—	*0.15*
Long Bone	—	—	—	—	—	*5.00*
Rib	—	—	—	—	—	*2.40*
Foetus	3.3	—	—	—	—	—
Whole animal (young)	2.0	—	—	—	—	—

viscera of cats and men. This work is certainly unsatisfactory technically, as is that of Keilholz (1921) who was unable to detect the element. McCollum, Rask and Becker (1928) concluded that aluminum was in general absent from both plants and vertebrate tissue, a contention challenged by

Kahlenberg and Closs (1929) in a paper that led to some controversy (McCollum, Rask and Becker, 1930). Underhill and Peterman (1929a) modified the alizarin technique which has been used by Keilholz, and found (1929b) aluminum in most of the tissues of fasting dogs; the gonad alone contained little or none of the element; the liver from 6.6 to 14.1 mg. per kilo. wet, the bile 9.2 to 29.9 mg. per kilo. wet, the thyroid from 23.5 to 124 mg. per kilo. A like accumulation in the thyroid had also been noted by Gray (in Smith, 1928), using a comparable technique on a much less extensive series of specimens. The results of these investigators, as well as of Underhill, Peterman, Gross and Krause's (1929b) study of human liver and kidney, are systematically higher than those of most other recent authors; Eveleth and Myers (1936a) have adduced strong reasons for believing that the presence of calcium vitiated the results. The disproportionately high thyroid figures are not confirmed by Myers and Mull (1928a) or Tourtellotte and Rask (1931b) on the rat, nor by the latter authors (1931a, b) on the dog, where 2 mg. per kilo. is regarded as probably excessive, nor by Mackenzie (1932) on the pig. The best mammalian data, based on reliable colorimetric or spectrographic methods, are probably those of Myers and Mull for the rat (1928a), of the same workers (1928b) and of Kehoe, Cholak and Story (1940a) for man, of Myers and Morrison (1928), and Eveleth and Myers (1936b) for the dog, and of Lehmann (1931a), and Meunier (1936) for a variety of mammalian tissues. The more certain data for the rat, dog, and man are summarized in Table 1. It will be observed that in general muscle and blood, as Lewis (1931) has also found for the latter in man, are very low in the element; most of the aluminum in the blood is present in the plasma (0.24 mg. per kilo.), the cells containing but 0.03 mg. per kilo. (Kehoe, Cholak, and Story, 1940a). Some of the viscera may contain, though not invariably, over one milligram per kilo. The very high mean value for the human lung is clearly due to contamination by dust. In view of the work on aluminum and silicosis discussed in a previous section, this high content may have some significance. The element appears to accumulate in human bone, though the experimental findings of Myers and Morrison on the dog indicate no such phenomenon. Confirmatory observations on the rat are given by Tourtellotte and Rask (1931b), who found 0.05–1.0 mg. per kilo. in the viscera, and by Hove, Elvehjem, and Hart (1938) as indicated below. Rusoff and Gaddum (1938), using a rather crude spectrographic method, obtained low values of the order of 0.001 mg. per whole newborn rat or about 0.2 mg. per kilo. wet. Schwartze, Cox, Unangst, Murphy, and Wigman found an average of 0.4 mg. per kilo. wet in the guinea pig. Mackenzie (1930, 1931), though he used Myers and Mull's technique, obtained higher figures for both pig and rat; the fresh liver of the former animal is said to contain 4.3–8.3 mg. per kilo., of the latter, 16–18 mg. per kilo. These results are doubtless excessive. Lehmann (1931a), analyzing beef muscle, and beef and cat liver, and Wührer (1933), studying the dog, obtained by gravimetric methods rather higher results than the investigators mentioned above. Wührer states he obtained fair checks with Underhill and Peterman's technique; this fact alone suggests that his gravimetric determinations are too great. Very much higher values than those just presented have, however, recently been obtained for human liver by Lundegårdh and Bergstrand (1940). These investigators used a spectrographic method, said, in the case of aluminum, to provide individual determinations of which the error is not greater than 10 per cent. The range recorded for the entire material of 376 cases is very great, from 1.1 mg. per kilo. wet to 109.4 mg. per kilo. wet. The lowest values just overlap those expected on the basis of the works admitted above, but the means obtained by weighting equally four disease groups, causing death, but unlikely to affect the liver, are 27.1 mg. per kilo. wet for males and 27.4 mg. for females, values entirely out of harmony with the concordant results of Myers and Mull and of Kehoe, Cholak, and Story. In Laennec's cirrhosis abnormally high values appear to be usual, and it is suggested that the injured cells are unable to exclude the element. A considerable increase in liver aluminum is recorded during childhood, but in view of the adult variability this may not be significant. Taken as a whole these findings are puzzling. They cannot be lightly dismissed but are oddly at variance with the data which would otherwise be most acceptable, and this is rendered more curious by the fact that for other elements (Zn, Rb, Cu, Mn) the results of Lundegårdh and Bergstrand agree with those of other investigators. Apart from the analyses given by Lundegårdh and Bergstrand, a few observations exist on the variation of the aluminum

content of mammals with age. Thus Underhill and Peterman claimed that young embryo dogs contain no aluminum and that apart from isolated occurrences in muscle, the element is first constantly present in the lung from the third week after birth, appearing in the liver only after three months of life. Schwartze, Cox, Unangst, Murphy and Wigman, however, say that the aluminum outside the viscera declines with age in the guinea pig. Rusoff and Gaddum conclude from their finding of aluminum in the rat neonatus, that the element undergoes placental transmission. Records of aluminum in milk have been given by various authors, notably Wright and Papish (1929), and Drea (1934, 1938).

Considering only the most consistent, non-human, data, the mean aluminum content of living mammalian viscera would appear to be about 1.0 mg. per kilo. or 10^{-4} per cent, while the musculature contains considerably less; an estimate of 5×10^{-5} per cent for the whole mammalian body is therefore reasonable. This is about one-fortieth of the amount present in the herbaceous vegetation on which the terrestrial vertebrates ultimately depend for their food; human vegetable food, being highly selected, apparently contains less aluminum than would that of the average herbivore. Such an estimate is confirmed by Meunier's (1936) analyses, which are not strictly comparable to the others, being related to dry weight, but which indicate an amount of the same order of magnitude. Meunier finds the lowest amount, 1.2 and 1.6 mg. per kilo., in the lingual musculature of the ox and horse respectively, the only muscles studied; the highest amount, namely 16 mg. per kilo., he found in the pancreas of the horse. His means, weighted heavily in favor of the viscera, for horse and ox tissues, were respectively 8.8 and 9.4 mg. per kilo. and clearly correspond to the same order of concentration as do the American results. Somewhat lower figures are given for the content of the liver and pancreas of the foetal ox (2.4, 2.6 mg. per kilo.), the sheep (2.0, 4.9 mg. per kilo.), and the pig (3.4, 4.8 mg. per kilo.).

Information as to the aluminum content of the other groups of vertebrates is very meagre. Drea (1935) records aluminum spectrographically in the chick 48 hours after hatching, the strongest indications being in the heart, kidney, lung, and muscle. This is hardly concordant with the quantitative mammalian data. Berg (1913) found about 2 mg. per kilo. in egg-yolk and but a trace in the white. Lehmann (1931a) records considerably more, namely, 3.8–5.8 mg. per kilo. of yolk and 0.2 to 0.9 mg. per kilo. of white. The spectrographic studies of Tourtellotte and Rask (1931a) suggest these figures are too high; for whole eggs they found 0.05 to 0.5 mg. per kilo. Cazzaniga (1935) also records Al in both yolk and white of birds' eggs. Berg gives some data for edible freshwater fish in which he found up to 0.0015 per cent of the wet weight to be Al. This result seems too high and the best data are doubtless those of Skanavi-Grigorieva (1939) who records in *Cyprinus carpio* 8.3×10^{-5} per cent wet weight or 4.71×10^{-4} per cent dry weight to be aluminum, and in *Tinca tinca* 1.16×10^{-5} per cent wet weight or 5.9×10^{-4} per cent dry weight. Winter and Bird found 3.0 mg. per kilo. wet or 15.8 mg. per kilo. dry in "white fish" (*?Coregonus*), 3.1 mg. per kilo. wet or 7.8 mg. per kilo. dry in the cod (*Gadus*) and 8.8 mg. per kilo. wet or 11.0 mg. per kilo. dry in the herring. The source of the last specimen, which must have been partly dried, is not indicated. Comparable figures are given by Meunier for the aluminum content of the musculature of *Labrax* (3.6 mg. per kilo. dry) and of a dog-fish (7 mg. per kilo. dry). These data at least serve to show that the low values obtained by recent students of the aluminum content of the mammalia are characteristic of the vertebrates in general.

Three curiosities demand brief mention, since they are listed without comment both by Langworthy and Austen and by Mellor, and therefore may give rise to misconceptions, though all three are probably devoid of interest. M'Murtrie's (1874) record of almost twenty per cent alumina in material described in the title of his paper as *Bat-Excrement*, is admittedly based on a cave deposit rich in both bat guano and in mineral matter and implies no excessive aluminum metabolism in the Chiroptera. Walter (1889) found considerable alumina in the material that collects over specimens of *Protopterus annectens*, but comments on his findings only to prove that the material, which apparently forms a protective coat during aestivation, is partly of external origin. Thezard's (1895) record of a small amount of alumina (0.534 per cent), admittedly of probably extraneous origin, in a bleached and cracked tibia from an Egyptian tomb of unknown age near the Step Pyramid at Sakkarah and presumably de-

rived from a decayed mummy, merely throws a melancholy light on the powers of selection of some chemists in choosing material on which to exercise their skill.

THE PHYSIOLOGY AND POSSIBLE BIOLOGICAL FUNCTION OF ALUMINUM IN ANIMALS

Few deficiency experiments have been attempted. Osborne and Mendel (1913), in preparing a purified diet for growth studies, found that the addition of traces of fluorine, aluminum, and manganese produced improved growth. No attempt was made to study the rôle of these elements separately. Daniels and Hutton (1925) found that the addition of fluorine, aluminum, silicon, and manganese greatly improved the development and particularly the fertility of rats fed exclusively on milk to which iodine and iron had been added. Comparable results were recorded by Mitchell and Schmidt (1926). The results of Daniels and Hutton on addition of one, two, or three of these elements, were less satisfactory and are hard to interpret. It is particularly curious that omission of manganese, the only one of the four elements generally credited with a biological function, had a less drastic effect than the omission of fluorine and silicate. Some of the experiments gave an impression that aluminum was necessary for reproduction in the rat. No certain conclusions, however, can be derived from the investigation. The rats reared on a diet low in aluminum, of which analyses were given by Myers and Mull, were received from Daniels.

In a brief report Doty (1933) found that normal growth and reproduction were obtained when the aluminum intake of rats was reduced to 0.3–0.4 mg. per kilo. of food. The most critical work, however, is that of Hove, Elvehjem, and Hart (1938). Using a milk diet supplemented with iron, copper and manganese salts of known purity, they computed that each rat would obtain 1.0–1.5 γ Al per day from the milk. Such rats were compared with others given 10 γ and 30 γ Al per day. The mean growth rates, and Al contents of blood and liver of the three series were as follows:

	Mean growth rate (g. per day) ♂	♀	*Al in blood (γ per 100 cc.)* ♂	♀	*Al in liver (γ per kilo. wet)* ♂	♀
1.0–1.5 γ per day.....	3.24	2.41	13.2	14.7	90	107
10 γ per day added....	3.56	2.77	15.6	13.6	130	140
30 γ per day added....	3.50	2.39	23.0	20.0	265	290

The apparent optimum in growth rate at 10 γ per day is regarded by the authors as probably not significant; it is unfortunate that no statistical significance test was applied. Hove, Elvehjem, and Hart conclude that, if aluminum is needed by rats, the need is clearly satisfied by 1–1.5 γ per day. In view of the slightly higher growth rate of the 10 γ series, it is worth noting that Myers and Mull found a slightly greater initial growth rate in rats given 2 mg. Al per day than in rats fed a normal diet. The quantities of aluminum ingested in Myer's and Mull's control were doubtless greater than in Hove, Elvehjem, and Hart's experimental series, so that no valid conclusions can be drawn. Hove, Elvehjem, and Hart found reproduction continued on their low aluminum diet, though in all series conditions were unsuitable for the rearing of young. On the whole, these experiments do not suggest any function for aluminum, but it must be pointed out that, though the liver of the low-aluminum animals contained less of the element than is recorded in other determinations, the amount present (about 0.1 mg. per kilo. wet) corresponds to about fifteen million atoms per liver cell, and is not reduced in proportion to the reduction of the aluminum content in the diet. This must be borne in mind in considering the action of aluminum as a cofactor in the enzymatic oxidation of succinic acid, to be discussed in the next section.

Apart from these experiments, a few authors have expressed opinions as to possible metabolic functions. Papillon (1870) believed he had found 6.95 per cent Al_2O_3 in the bone of a young rat fed aluminum phosphate, and he concluded that aluminum could in part replace calcium in bone formation. The high figure, on which this improbable conclusion was based, is undoubtedly erroneous; working a few years later, König (1874) was unable to confirm Papillon's result. Myers and Morrison found but 0.4 mg. per kilo. in dog's bone after prolonged aluminum feeding, though the most recent work, as has been indicated, seems to indicate that there may be a very slight accumulation of the element in the mammalian skeleton. Balls (1920) claimed that when freshly precipitated aluminum phosphate was fed to dogs, the element appeared in various organs, and that the highest concentrations were in bone-marrow (8 mg. per kilo.) and in the so-called ferritin fraction of a liver extract (600 mg. per kilo.). He believed that, in general, aluminum, when absorbed, followed iron in metabolism, though there was far less storage in the liver. A subsequent and ap-

parently unpublished experiment quoted from Balls by Smith (1928) failed to show the great concentration of aluminum in ferritin obtained from a puppy that had been fed aluminum. Balls compared aluminum to iron chemically and concluded their similarities justified his interpretation. Though this comparison of iron and aluminum is largely specious, recent investigations of ferritin suggest that the possible replacement of part of the ferric iron held within the molecule of this remarkable protein (Granich and Michaelis, 1942), by aluminum, might be worth investigating. Balls, however, regarded aluminum as usually absent from normal tissue, so he presumably did not mean to suggest a functional significance for his results. Other suggestions, as that of Bertrand (1920), refer merely to a vague biocatalytic function of the element. Such ideas are probably derived mainly from the writings of Stoklasa, and although based at the time on no adequate experimental data, appear now to be justified by at least one investigation. The recent study of Roffo (1940), who found that young rats grew better in copper than in aluminum cages, better in aluminum than in iron, lead, zinc or wooden cages, presumably lies on the shadowy periphery of scientific endeavour.

A curious protective effect has been noted by Sharpless (1935) who found that an excess of aluminum (0.224 per cent Al as $AlCl_3$) in the food of rats almost abolishes the dental symptoms produced by 0.025 per cent NaF. The quantity of aluminum in relation to fluorine is here much greater than in cryolite which is known to be active in producing mottled enamel. It seems just possible that the lower activity of fluorine accumulated in tea in producing mottling, noted by Lawrenz and Mitchell (1941), may be due to the presence of aluminum.

Aluminum and the succinic dehydrogenase-cytochrome-C system

Analogy with the metabolic behavior of other trace elements might suggest, as has indeed been implied in the writings of Bertrand and of Stoklasa, that any function that aluminum might be found to possess would probably be due to the element playing a specific rôle in some enzymatic catalysis. Yet in plants, in which aluminum is widely distributed, and in which several indications of function have already been given, no case could be analyzed in this way, with any degree of confidence. Parenthetically it may be remarked that Bortels (1939), in a paper overlooked until after the printing of the second part of the present review, has indicated that in the absence of molybdenum, vanadium, and manganese, and in the presence of both silicon and iron, aluminum can produce some stimulation of nitrogen fixation by *Azotobacter vinelandii*. The conditions under which the effect was observed are so restricted that this case cannot be regarded as satisfactory until it has been studied further. It is indeed rather surprising that the first good example of aluminum taking part in enzymatic catalysis should have been obtained from animal material, admittedly poor in the element.

Horecker, Stotz, and Hogness (1939) found that minute amounts of aluminum added to a mixture of sodium succinate, cytochrome C, and an enzyme preparation from beef heart muscle, greatly promoted the rate of oxidation of the succinate. The smallest quantity of aluminum giving a maximum rate of oxidation is about 10 γ in 3.3 cc. of the solution of the reactants, corresponding to about 3 mg. per litre. A like but somewhat greater effect was obtained with tervalent chromium, while neodymium, lanthanum and samarium also proved active. The addition of ferric chloride had no effect; magnesium was likewise inactive, manganese seems to have reduced the rate of oxidation, zinc produced total inhibition. Horecker, Stotz, and Hogness conclude, by extrapolating their curves relating aluminum added to the preparation to activity, that the spectrographically estimable traces of aluminum in the enzyme preparation are of the right order of magnitude (1.5 γ in 0.1 cc. enzyme) to account for the observed activity of the enzyme preparation prior to the addition of aluminum, on the assumption that a tervalent ion is actually required. The quantity of chromium in the enzyme preparation (< 0.1 γ in 0.1 cc.) is too low to be significant in the natural enzyme system, and the rare earths are doubtless rarer still. As far as the evidence goes, this work strongly suggests that aluminum forms an integral part of the system. At the time this work was done, the oxidation of succinate in this system was known to involve at least two reactions catalyzed enzymatically. The first is the reduction of cytochrome C by the succinate in the presence of succinic dehydrogenase, the second the reoxidation of the cytochrome C in the presence of cytochrome oxidase. A parallel but quantitatively less important reduction of cytochrome B also proceeds in the preparations studied. This is apparently unaf-

fected by aluminum. Horecker, Stotz, and Hogness were able to show that it is very unlikely that aluminum has any effect on the oxidation of cytochrome C reduced by paraphenylenediamine or on the succinic dehydrogenase when methylene blue is acting as hydrogen acceptor. The effect is apparently limited to the naturally integrated system. They suspected that a very minute amount of aluminum hydroxide is coprecipitated with the enzyme in their preparations, and it is this coprecipitate that is active.

The matter has been further studied by Potter and Schneider (1942). It is now known that a third enzyme, cytochrome reductase, plays a part in the system, and that calcium ions are needed as well as tervalent ions. Potter and Schneider studied the decrease in activity in the system that occurs as the result of homogenizing liver. This decrease is attributed to the breakdown of the cellular structure of the tissue, so that the enzyme system is dispersed through a greater effective volume than in the cell. This dilution, caused by the destruction of the natural morphological localization of the system, results in dissociation of the metallic ions from the enzyme complex, so that the concentration of the ions must be raised in order to restore the original activity exhibited in the living cell. Potter and Schneider conclude that since aluminum is not involved when methylene blue is the end acceptor of hydrogen, but is, when cytochrome C is the acceptor, that the aluminum acts as a cofactor in the reaction between cytochrome C and its reductant, tentatively considered to be succinic dehydrogenase. Other evidence indicates that the reaction of the latter with the succinate requires calcium as a cofactor. The theory of Horecker, Stotz, and Hogness, as to the coprecipitation of the complex with aluminum hydroxide is ruled out, according to Potter and Schneider, because the aluminum effect is dependent on the presence of adequate calcium. Potter and Schneider confirm the possibility of substitution of aluminum by tervalent chromium, but in view of the scarcity of the latter in the animal body, it may be presumed that it is aluminum and not chromium, and *a fortiori* not the rare earths, that acts as the natural cofactor. It must, however, be pointed out that none of these investigators has considered the properties of gallium, which possibly might be present in mammalian tissues in adequate quantities, though, owing to the extreme volatility of its chloride and the low sensitivity of its *raies ultimes*, it would easily be missed in the preparation and spectrographic study of animal ashes by the usual procedures.

The metabolism of aluminum in vertebrates

A number of workers has studied the fate of aluminum compounds ingested with foods, mainly with a view to determining whether sodium aluminum sulphate in baking powder is likely to have an unfavorable effect on human health. It is now widely, though not quite universally, agreed that the older conclusions of Smith (1900) and of the Referee Board of Consulting Scientific Experts (U. S. Dept. Agriculture Bulletin (Professional Paper) 103, 1914) are correct and that the quantities of aluminum, normally ingested from this source or from aluminum cooking vessels, are innocuous. In spite of these results a number of claims, based apparently on little or no objective evidence, and in part probably inspired by commercial interests, continues to be made. A group of small books has appeared, largely constructed by juxtaposition of isolated quotations from newspapers and from the work of investigators of varying degrees of maturity. As examples, may be mentioned Betts (1928?), and Keens (1937) whose work bears the arresting title of *Death in the Pot*. The former tells us that "Chauser" used the word "alum," figures an aluminum device used in the illegal aging of whisky, and compares the "catalystic action" of aluminum with that of radium. Keens, quoting a remark on the carcinogenic action of the radiations of mesothorium and radiothorium, comments that "aluminum resembles thorium and uranium in many respects." These two works are devoted to the thesis that aluminum poisoning is an important cause of cancer, a claim which is clearly inconsistent with most laboratory experience, and which has been adequately refuted by the special studies of Bertrand and Serbescu (1931, 1934a, b). Other authors have attributed other diseases to the same cause. The existence of a goodly crop of ephemera of this kind is well known whenever a controversial scientific subject assumes great practical importance; however much they may enliven the task of the exhausted bibliographer, they are so misleading to the general public that they should be allowed to remain undisturbed in the dusty limbo believed to contain other like works. Specific replies to the claims of toxicity are given by Smith (1928), Lehmann (1931b) and Burn (1932). Monier-Williams

(1935) looks with disfavor on alum in baking powder but concludes that aluminum vessels have had no widespread deleterious effects. He makes the interesting suggestion, however, that certain individuals may be abnormally sensitive to aluminum poisoning. The more significant claims against the element are well reviewed in his paper, while the opinions of numerous public health authorities, and the editorial comments from responsible medical journals have been admirably summarized in the *Select Annotated Bibliography on the Hygienic Aspects of Aluminum and Aluminum Utensils* (Mellon Institute of Industrial Research, 1933). Chittenden, testifying for the Referee Board (Smith, 1928) reports that 150 mg. Al per day is without obvious effect on normal individuals; 200 mg. or more may, however, give rise to mild catharsis, which naturally increases with the dose. The various authors who have studied the metabolic fate of aluminum, have administered to a variety of animals considerably greater amounts, usually without any ill effects being observed. Lyman and Scott (1930) could detect no result of 8 mg. per day fed to rats, which represents a very much greater dose. The histology of rats given food containing 3.6 per cent $AlCl_3 \cdot 6H_2O$ was found to be normal by Scott and Helz (1932). The slight stunting of growth observed in rats when large amounts, up to 1.7 per cent Al in the food is given as aluminum phosphate, is probably due to the ingestion of smaller quantities of the salt, unpalatable food (Mackenzie, 1932). As will be pointed out later, such large dosage is only innocuous when the diet contains a stoichiometric excess of phosphorus; this is normally the case in laboratory experiments.

It is generally agreed that aluminum, either occurring naturally in food or administered in experiments, is eliminated, almost, if not quite, quantitatively, and that most of this elimination occurs with faeces. Thus Smith (1900), and Schmidt and Hoagland (1919), found quantitative elimination in the faeces in adult man. More delicate methods have generally indicated some urinary excretion. After experimental feeding of aluminum, Flinn and Inouye (1928) found 30 per cent to be eliminated by the rat in urine, 70 per cent in faeces. Myers and Mull likewise found aluminum in the faeces of aluminum-fed rats, and though Mackenzie claimed quantitative faecal elimination in both the pig and rat, his individual figures for the latter animal vary from 74.9 to 114 per cent of the ingested aluminum in the faeces, and leave room for a small average urinary excretion. Myers and Morrison, to name only the most reliable of a number of workers, observed urinary excretion after aluminum feeding in the dog. Kehoe, Cholak, and Story (1940a) found at least 0.01 mg. per litre in all but one of twenty-eight samples of human urine; the mean was 0.052 mg. per litre. It might conceivably be argued that the original path of entry of this was the epithelium, not of the alimentray tract, but of the lung. Such an explanation is not, however, possible when, as in the previous experiments a considerable quantity of aluminum is recovered after increased oral intake, and is unlikely in the next study in which a balance sheet for "normal" aluminum intake is presented. Scoular (1939b), studying the normal aluminum balance in growing pre-school age children, found a slight positive balance in seven experiments, a slight negative balance in eight, and in two experiments obtained exact equivalence of income and output. The mean value is negative, but not significant, namely, -0.0005 mg. per kilo. of body weight. In general more than half the balances could be due to experimental error, and the remainder clearly provides no evidence of systematic retention, such as was found for copper and zinc (Scoular, 1938, 1939a). Some aluminum always appeared in the urine; in individual cases this represented up to 30 per cent of the intake; the mean percentage figures for excreted aluminum are 19.5 per cent in the urine and 80.5 per cent in the faeces.

The preponderance of faecal elimination naturally leads to some doubts as to whether much aluminum is actually absorbed from the alimentary canal. Though Myers and Killian (1928) appear to have satisfactorily established that some aluminum can exist in solution in both the human stomach and in the duodenum, direct attempts to demonstrate absorption from exposed loops of the gut have not yielded unequivocal results (Myers and Morrison, 1928; Mackenzie, 1932). The appearance of aluminum in the blood after oral administration has been extensively studied. The techniques used by the earlier investigators are clearly inadequate for this purpose, as the concentration, even during absorption, is very small. Lewis found a trace present in two men, four and a half, and forty-eight hours, respectively, after administration; control samples taken before the meal lacked spectrographically detectible aluminum.

The experiments of Underhill and Peterman (1929b) apparently indicate an increase of blood aluminum after aluminum feeding of dogs, but their method, as has been pointed out, is imperfect. Underhill, Peterman, and Steel (1929) believed that at least some aluminum in the intestine was absorbed by the lymphatics, a possibility not considered by other authors, but perhaps of interest. Kärber (1933) found little uptake in the cat from tenth molar solutions of aluminum chloride, nitrate or aluminum sodium tartrate. The addition of urea increased the permeability of the intestinal wall to aluminum, but this is of little interest in the normal physiology of the element. The fact that all investigators have found aluminum in the bile indicates that some of the aluminum present in the faeces, as well as in the urine, has been involved in a metabolic cycle. It is conceivable that this aluminum has in part entered the blood stream through the pulmonary epithelium, but if such a mode of entry were generally important significant negative balances would have been reported wherever balance sheets have been made.

Experiments have been made on several occasions by injecting aluminum intravenously or intraperitoneally, and studying the mode of excretion. Underhill, Peterman and Steel found aluminum to appear in both urine and bile after such injection, as well as in the lymph. They also believed that direct excretion into the alimentary canal across both gastric and intestinal walls occurred. Myers and Morrison, and Eveleth and Myers, whose chemical technique was more accurate, also found excretion in both faeces and urine; they failed to obtain unequivocal evidence of an increase in bile aluminum after injection. Much storage takes place in the liver, and some in the spleen, after such injections.

Much can be learned from analyses of organs of animals fed known amounts of the element in excess of that present in the diet of controls. All modern authors agree that prolonged aluminum feeding causes at most but a slight increase in the aluminum over the content of control animals fed ordinary diets. Myers and Mull found an increase in the livers of rats from 1.4 to 1.8 mg. per kilo. when 2 mg. Al per day were administered, but the individual figures are variable; when other organs are considered decreases as well as increases in mean Al content occur, so that no great stress can be placed on the results. Somewhat more certain figures were obtained for the dog by Myers and Morrison; the mean content of the liver rose from 1.5 mg. per kilo. (range 0.8–3.1) to 2.7 mg. per kilo. (range 1.2–4.2). The heart, kidney and spleen showed no increases. Wührer found little or no increase in experiments with the dog, Mackenzie little in the pig and none in the rat. Underhill and Peterman produced some evidence of an increase in bile aluminum at the beginning of such an experiment followed by a fall almost to the level of the control after some weeks administration of the element. In view of the excessive values given, the meaning of these results cannot be evaluated. Considering only the technically satisfactory work, we may conclude that on a normal diet the aluminum content of the organs is relatively little influenced by addition of aluminum salts. When, however, we consider the results of Hove, Elvejhem, and Hart already given, we find that a reduction in aluminum intake does have a striking effect on the aluminum content of the rat's liver. Since we may assume ideally that on a completely aluminum-free diet (including the intake of the embryo), none would be found, we may conclude, from the data of these investigators, already given, that the curve relating intake of aluminum to the aluminum in the liver rises rapidly at first, but begins to flatten off almost immediately. The slope of the part of the curve between 10 γ and 30 γ per day, however, is still great enough to be inconsistent with a content of 1400–1800 γ per kilo. in Myers and Mull's experiments in which the control and experimental animals presumably received 1000–3000 γ per day. The best interpretation of these results therefore would appear to be that the aluminum content of the rat's liver can be raised by oral administration only to approach a certain definite limiting concentration. Since in injection experiments, amounts as high as 92 and 72.5 mg. per kilo. can be found in apparently healthy livers after interperitoneal administration of 4 mg. of aluminum as potash alum, it is clearly not the liver itself that sets the limiting concentration. The simplest explanation would be that the upper limit represents a steady state determined by the solubility of $AlPO_4$ in that part of the gut from which absorption of the element takes place, and by the rate of elimination by whatever excretory organs are involved. It is, however, unlikely that so simple a mechanism is involved, particularly as aluminum phosphate in the gut seems fairly soluble, at least in the stomach

and duodenum. It is of considerable interest to note that in certain experiments on plants, a similar limiting concentration in the leaves, independent of the concentration in the environment of the roots, has been reported.

Aluminum and phosphate metabolism

From the beginning of the controversy regarding sodium aluminum sulphate baking powder, it has been claimed, by those objecting to such preparations, that their use prevented the absorption of phosphate from the gut. In the first litigation (Warren v. Phillips, 1879), namely the Norfolk Baking Powder Case, tried at Cambridge, England, much of the expert evidence, given by certain well-known chemists and physicians (M. M. Patterson Muir, J. B. Bradbury, Paget), concerned this possible action. This evidence was admittedly inadequate and contradictory, and though the magistrates had found the defendant guilty, the case was reversed on appeal by the Recorder of Cambridge. Subsequently the same objections have been frequently voiced, and an investigation of their significance formed a part of the work of the Referee Committee. The investigations conducted by that body indicated that ingestion of moderate amounts of aluminum, such as would occur in food prepared with aluminum baking powders, did indeed cause a slight deflection to the faeces of phosphorus that would normally have appeared in urine. Similar results were obtained by Hoagland and Schmidt. With massive doses on a low phosphate diet, Leary and Sheib (1917) noted a slowing of growth.

Cox, Dodds, Wigman, and Murphy (1931) found that when 1400 parts per million aluminum was added to the diet, the amount being in stoichiometric excess of the phosphate, which corresponded to 1350 p.p.m. aluminum, the ash, calcium and phosphorus of the bone of guinea-pigs were reduced to 70 per cent of normal in 12 weeks, and the inorganic blood phosphorus likewise fell to 30 per cent of normal. A similar addition to the diet of rabbits practically abolished excretion of phosphorus in urine in 9 days.

Deobald and Elvehjem (1935) obtained similar results with chicks, using half or three-fourths the amount of Al required to combine with the total phosphorus of the food. Serum phosphorus fell as low as 2.1 mg. per 100 cc. when 0.22 per cent of the food was Al and 0.51 per cent P, and a markedly rachitic condition intervened. They record, however, a tendency for the serum phosphorus to rise somewhat when the highest Al content (0.44 per cent of food) was used; apparently this is due merely to dehydration of the blood during very severe rickets. Addition of 5.77 per cent Na_2HPO_4 to the diet, even when containing 0.44 per cent Al, permitted a normal serum phosphorus value of 6.2 mg. per 100 cc. The bone ash in such individuals was normal (44.72 per cent), of the aluminized but phosphorus-deficient individuals, very low (24.61–31.74 per cent). Jones (1938) found that 4 per cent basic aluminum acetate or 5 per cent $Al_2(SO_4)_3 \cdot 18\ H_2O$ added to a stock diet produced a markedly rachitic condition in rats. Similar effects were produced by beryllium and strontium carbonates. Contrary to previous reports, this rachitic condition can be prevented or cured by sufficiently massive doses of irradiated ergosterol. Loss of ash from the femur takes place in adult rats on the 5 per cent aluminum sulphate diet. Serum phosphate decreased, presumably causing loss of phosphorus from the bones. No indication of the fate of the calcium that must have been liberated at the same time was obtained. Recently some attention has been given to the problem of dietary phosphorus utilization in the presence of aluminum hydroxide preparations, as these have been used in treatment of peptic ulcer. Fauley, Freeman, Ivy, Atkinson and Wigodsky (1941) find that aluminum hydroxide equivalent to twice the dietary phosphorus causes a reduction of urinary phosphorus to half its normal level in the dog, and believe that aluminum compounds can remove phosphate from the mucosa of the gut. Street (1942, Street and Barlow, 1941), using a markedly acid-soluble preparation of aluminum hydroxide found that inorganic blood phosphate and growth rate were much less depressed than by the equivalent amount of aluminum sulphate. He concluded that but 23–30 per cent of the hydroxide became soluble and capable of reacting with phosphate, and that in the therapy of peptic ulcer the danger of immobilizing phosphate with aluminum hydroxide is not serious.

A curious corollary of the observations of the preceding paragraph is provided by the fact that in parathyroidectomized animals, in which the calcium: phosphate ratio of the blood becomes greatly reduced, administration of aluminum salts, by lowering the blood phosphate, actually produces highly beneficial results (Jones, 1936; Bodansky and Duff, 1941). A dangerous reduction of blood phosphate and a rachitic condi-

tion can also be produced by stoichiometric excesses of iron, and as has just been mentioned, of strontium or of beryllium (Guyatt, Kay, and Branion, 1933), though in the case of the last element there is some evidence that mere precipitation as beryllium phosphate is not the only mechanism involved (Sobel, Goldfarb, and Kramer, 1935).

These experiments are of considerable interest ecologically, because it is clear from them that the more remarkable aluminum accumulator plants, such as *Symplocos*, *Lycopodium* spp. of the subgroup *Complanatostachys* and probably some of the *Melastomaceae* and *Diapensiaceae* would be impossible as the *sole* diet of any herbivorous vertebrates, though at least in the case of *Symplocos tinctoria*, cattle appear to enjoy the leaf. Little is known as to the mechanisms of phosphorus assimilation in invertebrates, but it is not impossible that such plants would again not be suitable as the exclusive diet of phytophagous species. It is therefore conceivable that the final evolutionary step in producing a marked aluminum accumulator at least protects the plant from monophagous herbivores.

SCANDIUM AND THE RARE EARTHS

The remaining elements to be considered are best treated in two groups. In the first group are scandium, yttrium, lanthanum, and the associated rare earths, conveniently termed by Goldschmidt the lanthanides. The second group comprises gallium, indium, and thallium. Though the latter three metals have the electronic configuration of typical elements, with three valency electrons in the outer shell, they all are of variable valency and geochemically behave less like aluminum than do scandium, yttrium, and the lanthanides. The rare-earth elements are therefore considered first.

Scandium, yttrium, and the lanthanides are strongly lithophil elements. Geochemically scandium differs from aluminum and from the rare earths in being about equally abundant (5 grams per ton) in the silicate phase of meteorites and in terrestrial rocks. In general the tervalent scandium ion, having a radius (0.83Å) comparable to that of the divalent Mg ion (0.78Å) enters basic magnesian rocks. The other elements are more or less concentrated in the more acidic products of late crystallisation. In meteorites the atomic ratio Sc:Y:La is about 15:10:2, in terrestrial rocks about 3.3:10:4.3, with increasing ionic radius the elements becoming more lithophil, and more basic. The heavier lanthanides are progressively slightly less basic and of smaller radius, so that there is an enrichment of the lighter "cerium earths" (La, Ce, Pr, Nd, Sm, Eu, Gd) over the heavier "yttrium earths" (Tb, Dy, Ho, Er, Tu, Yb, Lu) when the materials of the accessible lithosphere are compared with the silicate phase of meteorites. In all normal inorganic assemblages of the rare earths there is a very marked alternation of abundance according to the Oddo-Harkins rule, the elements of even atomic number being five to ten times as common as their neighbors of odd atomic number. The existence of one of the latter, namely, element 61, often called illinium, has not been adequately established.

In the accessible lithosphere the quantity of scandium may be taken as about 5 grams per ton, of yttrium as 28 grams per ton, of the lanthanide series together as 120 grams per ton, of which lanthanum (18 g. per ton) cerium (46 g. per ton) and neodymium (24 gm. per ton) are by far the most abundant constituents. The general abundance of the other elements is given in Fig. 5.

The presence of rare-earth elements in soil is well established. Robinson (1914) found from 0.01 to 0.08 per cent rare-earth oxides in a group of American soils. Borneman-Starinkevitch, Borovick and Borovsky (1941) found from 0.010 to 0.048 per cent rare earths (Y + lanthanides) in the mineral material of six Russian soils, or in four air-dried soils 0.014 to 0.020 per cent. In three soils studied spectrographically yttrium, lanthanum, and cerium were abundant, giving the strongest indications on the semi-quantitative scale adopted, chemical analyses indicate cerium oxide to comprise 40–50 per cent of the whole rare earth content. Neodymium (about 16 per cent NO_2O_3) and gadolinium follow, while ytterbium, europium, erbium, lutecium, terbium and dysprosium were detected, roughly in the order of abundance given. The authors point out the remarkable occurrence of the generally rare elements, europium and lutecium. The presence of moderate amounts of these two elements of odd atomic number, in two soils, after removal of cerium, was particularly striking.

The data for sea water are limited to determinations by Goldschmidt (1937) who found:

Sc	0.04 γ per kilo.
Y	0.3 γ per kilo.
La	0.3 γ per kilo.
Ce	0.4 γ per kilo.

The ratio of cerium and particularly lanthanum to aluminum is slightly greater in the ocean than in terrestrial rocks, presumably owing to their lower ionic potentials.

The biogeochemistry and biological function of scandium

Scandium is very little known in organisms. Lippmann (1925) reports the element in molasses from Canadian sugar beet; the significance of such a record is doubtful. Scribner (1939) finds scandium present in three out of four of the rare-earth concentrates from hickory leaves that he examined, and also in black raspberry and grey birch leaves. In sweetleaf (*Symplocos tinctoria*) rather greater amounts were present. Except in this last plant, the quantity of scandium present is clearly less than that of yttrium, as would be expected on geochemical grounds. I. and W. Noddack (1940) report that some unspecified members of the group of nine marine organisms that they studied, contained traces of scandium, but in all cases there was less than 1 γ per kilo. of dry matter. This would correspond to less than 0.2 γ per kilo. of living substance, so that the concentration factor is less than 5, and therefore probably rather less than in the case of aluminum. It is, however, not impossible that the low concentration factor for scandium is greater than those for yttrium and the lanthanides. Lux (1938) reports 2–5 γ per kilo. of bone ash, or 1–2 γ per kilo. of fresh ox-bone. Yttrium was considerably more abundant.

In spite of the very minute quantities of scandium present in organisms, Steinberg (1939b) obtained evidence that the element is necessary to produce a normal yield of *Aspergillus niger*, when glycerol is used as the sole carbon source. With other organic compounds as sources of carbon the effect was not observed.

The biogeochemistry of yttrium and the lanthanides

The rare-earth elements have been recorded from time to time in biological material, but only recently have any adequate studies been made. In nearly all investigations yttrium has been treated with the lanthanides.

The first qualitative records in plants are those of Cossa (1878, 1879, 1880) who found lanthanum, cerium and didymium (presumably mainly neodymium) in the ash of tobacco, of rice, of beechwood and of the grapevine. He implies in the last of the three papers that he had studied other plants and seemed convinced that the presence of these elements was a normal occurrence. He also mentioned that the quantity present in the ash of beechwood was clearly greater than in that of rice, and he associates this with the greater ratio of calcium to magnesium in the former material. Cossa clearly believed that the biological accumulation of rare earths was comparable to their occurrence in apatites but not in magnesium phosphate minerals, which occurrences he had investigated extensively. The study of such minerals had indeed suggested his biological investigations. Cossa's remarks on this matter constitute another hint of the crystallographic conception of the organism that seems to have existed vaguely in the minds of certain nineteenth century investigators. Crookes (1883 a, b), shortly afterwards, reported about one part in one million of tobacco ash to be yttrium, corresponding, in view of the high ash content of *Nicotiana*, to about 0.5×10^{-6} per cent of the living plant. This figure is concordant with the amount of yttrium to be expected from the mean quantity of total rare earth elements recorded in subsequent studies.

Little further work was done till quite recently; two qualitative reports may first be mentioned. Byelaya and Borovick-Romanova (*fide* Borneman-Starinkevitch, Borovick, and Borovsky) are stated to have found, in 1930, lanthanum and yttrium in *Lithothamnion*, the same elements, with cerium, in the leaves of *Acer* sp. and terbium and ytterbium in *Lemna minor*. The presence of the two heavy yttrium earths, without indication of the commoner cerium earths, in the last plant, is curious. Richards and Troutman (1940) found lanthanum spectroscopically in yeast; the element was not detected in the media employed in growing the cultures and must be considerably concentrated by the cells.

Robinson, Whetstone, and Scribner (1938), investigating the composition of a hickory tree growing on the well-known pregmatite vein at Amelia, Virginia, found that the dry leaf contained no less than 0.20 per cent rare-earth oxides. This extraordinary concentration is doubtless due to the nature of the substrate, but subsequent work (Robinson, 1938; Scribner, 1939) has shown that there is always an appreciable quantity of rare earths in *Carya*, from 0.009 to 0.20 per cent of the dry weight of the leaf being oxides of these elements. In the same investigation, the dry leaf of *Symplocos tinctoria* was found to contain 0.029 per cent rare-earth oxides, grey birth leaves from

Maine 0.008 per cent and black raspberry from Amelia 0.016 per cent. The concentrates from the last two plants were clearly very impure and the figures given are therefore excessive. Certain other plants were studied, apparently with negative results.

Using more sensitive methods, Borneman-Starinkevitch, Borovick and Borovsky (1941) have further investigated the rare-earth content of eleven different plants. They find no rare earths

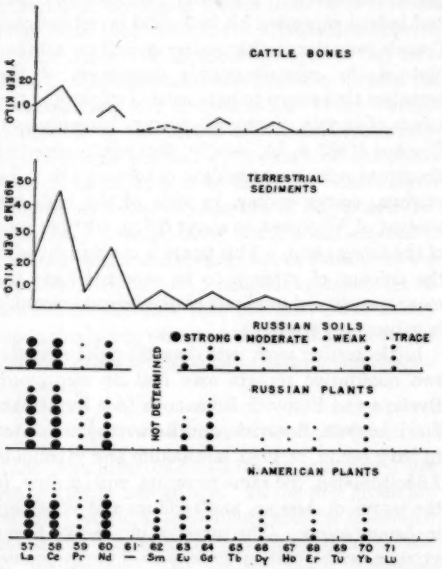

FIG. 5. THE DISTRIBUTION OF THE LANTHANIDES IN SEDIMENTARY ROCKS AND IN THE BIOSPHERE

in larch needles, and but 0.2×10^{-3} per cent in the ash of *Linaria genistefolia* (Scrophulariacea) while 5.1×10^{-3} per cent of the ash of the leaves of *Beta* and *Acer* consists of rare-earth oxides. The mean value for the ash content is 2×10^{-3} per cent. In six living plants containing the elements, the range is from 0.2×10^{-5} per cent in *Linaria* to 15.6×10^{-5} per cent in *Beta*. Including *Larix*, which did not contain the element, the mean for living plants is 4.2×10^{-5} per cent rare-earth oxides, so that a rough value of 0.00004 per cent for the elements is probably the most satisfactory estimate at present available for terrestrial vegetation as a whole.

Both Scribner and the Russian investigators examined the composition of their rare-earth precipitates spectrographically, recording the results semiquantitatively. These results are set out diagrammatically in Fig. 5, in which Minami's (1935) data for the abundance of the various elements in terrestrial sediments are also presented. In the American study it will be observed that the abundance of the even-number elements found in non-living matter is also exhibited by the rare earths from plants in a general way, but with two noteworthy exceptions. First, it is not possible to distinguish differences in the quantities of lanthanum and cerium, which are both present in abundance, and second, europium is more abundant than would be expected. The Russian data are more irregular, but on the whole show a similar distribution. A single determination of 16 per cent Nd_2O_3 in the rare earths of the ash of *Senecio paludosa*, not included in the table, indicates that neodymium is probably about as common relative to the other rare earths in plants as in terrestrial rocks. Borneman-Starinkevitch, Borovick, and Borovsky were not able to determine samarium, so that comparison is less easily made than in the case of Scribner's data, but again it would seem that europium is more abundant than would be expected. We have seen that the Russian workers have commented on the relative abundance of both europium and lutecium in soils. The latter element, however, is not transferred to the plant.

The American analyses reported by Scribner indicate that the major concentration of the elements is in the aluminum accumulators *Carya* and *Symplocos*. Hutchinson and Wollack (1943), however, found that the mixed phosphate and hydroxide precipitate from the ash of *Lycopodium flabelliforme* did not contain rare earths. Borneman-Starinkevitch, Borovick, and Borovsky claim that the rare earth elements are not quantitatively precipitated by ammonia in the presence of excess alumina. Hutchinson and Wollack isolated, at the same time as they investigated *Lycopodium*, a sample of rare-earth oxides from hickory. It is therefore probable that if any large amount had been present in *Lycopodium*, they would have detected it.

In marine invertebrates the occurrences are limited to the skeletal structures of coelenterates. I. and W. Noddack (1940) failed to find yttrium or the lanthanides in the marine animals that they investigated and concluded that the amount present was not greater than 1 γ per kilo. dry weight, or roughly not greater than 0.2 γ per kilo.

wet. Since Goldschmidt finds 0.3 γ of La and Y and 0.4 γ of Ce per kilo. of sea water, it would appear that the concentration factor is not greater than the order of magnitude of unity, and so probably even less than in the cases of scandium and aluminum.

In spite of this low capacity of the soft-bodied forms to accumulate rare earths, these elements occur in the calcareous skeletons of corals. Crookes (1883a, b) records in a "particular specimen of pink coral" no less than 0.5 per cent yttrium; this material, in fact, heads his table showing the occurrence of yttrium outside the rare-earth minerals. Later (1886) he states that yttrium occurs in "a Gorgonia of the species *Melithoea*" which doubtless refers to the same material. Yttrium is also recorded by Crookes from the Zoantharian coral *Mussa sinuosa*, while other Zoantharians, *Symphyllia* sp. and *Pocillopora damicomis*, are said to contain samarium. Crookes' all too brief remarks clearly are intended to imply separation of the two elements concerned from the other rare earths. His cases are indeed introduced into a discussion of the distribution of the rare-earth elements, as examples of such separation. Apart from an equally brief statement by Goldschmidt (1937) that he has proved "the presence of all rare-earth metals" in the calcareous skeletons of corals, and in very pure chalk from southern Sweden, nothing further appears to have been published on the matter. The problem should certainly be restudied using an adequate series of properly determined specimens, and all the resources of modern spectroscopy for the quantitative determination of the individual rare earths.

The rest of the work on the rare-earth elements in animals concerns their occurrence in vertebrates, primarily in skeletal material, which have been studied largely because of the known accumulation of rare earths in some inorganic hydroxyapatites. Cossa believed that he had isolated 30 mg. per kilo. of oxalates of lanthanum, cerium, and didymium from bones. Crookes found 1 part yttrium in 10,000 parts of ox bones. Gabriel (1893) failed to confirm these earlier records. Borneman-Starinkevitch, (*fide* Borneman-Starinkevitch, Borovick, and Borovsky), however, found 0.024 per cent in the ash of the tooth of the modern horse. More recently Lux (1938) has restudied the matter in cattle bones, but was unable to confirm the presence of any considerable amount of rare earths in bone. By using a mixture of praseodymium and thulium as a carrier, 3 mg. of a preparation enriched in rare-earth elements was obtained from 6 kilograms of fresh bone. There was considerable loss of the carrier elements during the concentration process, and so presumably of the naturally occurring rare earths. The quantities obtained are set out below, along with Minami's figures for terrestrial sedimentary rocks.

	In bone ash (γ *per kilo.*)	*In fresh bone* (γ *per kilo.*)	*In terrestrial sediments (Minami)* (*mg. per kilo.*)
Sc.....	2–5	1–2	5
Y.....	10–30	3–10	28.1
La.....	10.0	3.7	18.3
Ce.....	18.5	6.8	46.1
Nd.....	9.1	3.4	23.9
Gd.....	4.2	1.5	6.36
Dy.....	3.1	1.1	4.47

The use of praseodymium as a carrier precluded determination of the commonest rare earth of odd atomic number beyond lanthanum. No trace of the remaining odd-number earths was found. It is therefore reasonably certain that europium is not enriched in bones. Lux rather curiously compares the ratios of the amounts of the elements to each other to those obtaining in meteorites. He concludes that there is an enrichment in bone of the lighter, more basic, lanthanides. It is, however, well known that these members of the series are concentrated in the upper lithosphere, and when comparison is made (Fig. 5) with the proportions in the latter, it is seen that whereas lanthanum, cerium, and neodymium are about 2000 times commoner, gadolinium and dysprosium are only 1500 times commoner in rocks than in bone ash. This suggests the opposite relation to that postulated by Lux. Samarium, however, which is terrestrially as common as gadolinium, was not found, the amount present being not greater than 2 γ per kilo., so that there is considerable irregularity in the accumulation of the elements from their ultimate source.

The only non-skeletal record of rare earths in animals appears to be the findings of Schiapparelli and Peroni (1880a, b) of traces of lanthanum, cerium and didymium (i.e. presumably mainly neodymium) in human urine. They believed that the possibility of these elements playing a part in mammalian metabolism should be investigated.

The possible metabolic significance of the rare-earth elements

A number of experiments on the effects of rare-earth elements on various organisms has been made by many investigators. For the most part these experiments are ill-controlled and throw little light on the problems considered in the present review. Steidle (1935) has reviewed the earlier contributions, and though his summary is little more than an annotated list of references, it provides a fairly adequate account of the available information. Most workers have been interested in the rare earths either as potential antiseptics or drugs, or as tools in physiological research. Lanthanum, on account of its basicity, has been a favorite source of tervalent cations in studies of the effect of ions on living matter. Very little of this work has any bearing on the problems of the normal cycle of the elements in the biosphere. On the one hand, it is extremely improbable that any accumulations of physiologically active rare earths occur in the biosphere in toxic concentrations. Most experiments, however, relate to the toxicity of relatively concentrated solutions of these, in general, feebly toxic elements. There is on the other hand a slight possibility that in certain cases very low concentrations of the rare-earth elements may play a part in normal metabolism. Here, however, the experimental evidence is very meagre. Such data, bearing on this matter, as exist, are discussed below.

Using bacteria, several authors have found that dilute solutions of rare-earth salts stimulated both growth and metabolism. Frouin (1913) claimed some increased growth of *Mycobacterium tuberculosis* was caused by 0.005 per cent solutions of the sulphates of lanthanum, cerium, neodymium, praseodymium, and samarium. These elements, however, cannot substitute for magnesium, as Sauton is said (Frouin quotes Sauton (1912), a paper containing no remarks on this subject) to have found was possible in pigment formation in *Pseudomonas aeruginosa* (*sub Bacillus pyocyaneus*). Later Frouin and Guillaumie (1923) found that in a synthetic medium containing both glucose and glycerol, rare-earth salts stimulated *M. tuberculosis* at pH 6.7–7.0, inhibited at pH 5.2–5.6. If glycerol were not present, yttrium stimulated in the presence of 5 grams per litre of glucose at pH 5.8, inhibited at pH 7.0, but, in the presence of 20 grams glucose per litre, was inhibitory at both pH values. These effects, if real, are doubtless electrostatic in origin, but the presentation of the data is so inadequate that no objective judgment is possible. Girard and Audubert (1918) found that the electric moment of the double layer on a number of species of bacteria, measured electrophoretically, could be reduced by addition of small amounts of lanthanum and claimed that as a result of such reduction, a four to six-fold increase in the productivity of the cultures occurred. Shearer (1923), while confirming the electrophoretic results, could not obtain unequivocal indication of an increase in yield. Brooks (1921) found that 0.000006M lanthanum nitrate stimulated respiration in *Bacillus subtilis*, and Zirpolo (1922) that 1 in 20,000,000 cerous nitrate stimulated light production in luminescent bacteria.

Several studies have been made on yeast. Hébert (1907) found that alcoholic fermentation was unaffected by as much as 10 g. per litre cerium sulphate, and that a like amount of lanthanum sulphate had little effect. Other workers have found inhibition at high and stimulation at low concentrations. In one case (Neuberg and Sandberg, 1920) a pronounced stimulation has been observed, with ceric chloride, at a concentration as great as M/ 10. The experiments are, however, in general poorly controlled, particularly with regard to pH, and to the anions of the salts employed. Two series may be mentioned, as probably reasonably consistent among themselves.

Hara (1923) found total inhibition by cerium chloride at a concentration of 0.25 per cent and a transitory stimulation at concentrations below 0.01 per cent. Consistent results were obtained only with dilute suspensions. Steidle and Ding (1929) found that 1 per cent and 0.1 per cent yttrium nitrate ($Y(NO_3)_3 \cdot 6H_2O$) inhibited fermentation, 0.01 and 0.0001 per cent stimulated, while with samarium nitrate Steidle and Dürr (1929) could obtain no effect.

Niccolini (1930) found that praseodymium chloride is slightly inhibitory at all concentrations studied (3 per cent to 3×10^{-8} per cent) but the strongest solution was less inhibitory than the 3×10^{-1} and 3×10^{-2} per cent solutions. Such a maximum inhibition may be related to a maximum in coagulation of protein solutions such as egg albumen, found at about 0.1 per cent $PrCl_3$. Guidi (1930) found neodymium to stimulate alcoholic fermentation slightly when the concentration was 3×10^{-6} to 3×10^{-8}. Slight inhibition occurred at and above 3×10^{-2} per cent, but

no clear evidence of a maximum inhibition was obtained. Niccolini (1931), working with samarium chloride, found a stimulation above 5×10^{-6} per cent up to a maximum at 5×10^{-1} per cent $SmCl_3$; at 5 per cent inhibition was observed.

These observations are probably to be compared with various cases that have been reported of the action of rare earths in accelerating enzyme action *in vitro*. Such action is recorded for oxidase systems by Guidi and by Niccolini, and more convincingly by Gould (1936) who found that 5.26×10^{-4} M cerium nitrate increased the activity of bacterial amylase and 7.1×10^{-4} M cerium nitrate the activity of yeast invertase. The possibility of replacement of aluminum by the rare earths in the succinoxidase system has already been considered. It may also be mentioned parenthetically that rare-earth salts tend to inhibit blood coagulation, apparently by inactivation of thrombokinase.

Hébert claimed that *Aspergillus niger* was stimulated by 0.5 g. per litre of cerium sulphate, and with less regularity by 0.5–2.0 g. per litre of lanthanum sulphate. Working with *A. fumigatus* Sartory and Bailly (1921) found complete inhibition by 1 per cent solutions, stimulation by dilute solutions containing 0.0005 per cent, 0.0002 per cent, and 0.0001 per cent rare-earth elements. These workers claimed that a concentration of 0.0002 per cent was optimal in the cases of Nd, Y and Er, 0.0001 per cent in the cases of Pr and La. Steinberg's more recent work, however, almost certainly excludes the possibility of a functional rôle for the rare-earth elements at these concentrations.

Young (1935) found no clear stimulation of *Chlorella*, *Crucigena*, or the problematic "alga no. 4" by lanthanum, but 20 mg. per litre of yttrium stimulated *Chlorella* and in one experiment 0.02 mg. appeared beneficial to *Crucigena*.

The effect of rare-earth elements on the flowering plants has been studied in a desultory fashion by a number of workers. Most investigators have found inhibition by strong solutions of unknown pH and varying anion content. Three of the earlier contributions alone appear to deserve attention. Loew (1913) found cereals stimulated by 1–2 mg. per kilo. of "didymium" nitrate added to soil, but not by cerium. Evans (1913), using solutions of rare-earth carbonates in CO_2-saturated water, found that cerium, lanthanum, and yttrium produced maturation of hyacinths several days earlier than the controls. The effect was greatest with cerium, least with yttrium. The first two elements appeared to stimulate cell division, while yttrium appeared to be inhibitory. Lanthanum produced a striking elongation of the flower stalk. Acqua (1913) found cortical root-poisoning by cerium, similar to that recorded for aluminum; such investigations made on the toxicity of the rare-earth salts are probably all largely vitiated by lack of pH control.

The only study that can be regarded as reasonably satisfactory is the recent one by Drobkov (1937) who used a preparation of mixed rare-earth nitrates, added to a nutrient solution in which *Pisum sativum* was grown. The presence of 1 mg. per litre of rare-earth nitrate increased the yield of dry matter of the pod almost threefold, and the rest of the mature plant was about 50 per cent heavier than the controls. Higher concentrations proved less effective. The striking stimulation observed was largely confined to the period of flowering and seed production. Drobkov concludes that the rare earths in phosphatic fertilizers are of importance agriculturally, and makes the remarkable statement that bone meal may contain up to 0.8 per cent of these elements.

Drobkov's experiments, taken in conjunction with the analytical data already discussed, suggest that at least in some organisms the rare earths may have a functional significance, and the question of a physiological differentiation of the lanthanides immediately presents itself. Much work on the properties of the commoner members of the group has been done in vertebrate physiology; as a whole this work falls outside the scope of the present review. Little certain information can be gained from the experiments reported, but in the case of the available observations on the production of diastolic stoppage of the isolated heart by rare-earth chlorides, Niccolini believes that the observations are sufficiently uniform to compare the effect of the different elements. Taking lanthanum as a standard we find that the relative activities of the rare-earth elements that have been studied, are:

	Poikilothermal forms (Rana)	*Homiothermal forms (Rattus, Cavia)*
La	100	100
Ce	50	no data
Pr	100	20
Nd	100	20
Sm	2	500

Faced with the extraordinary difference in the reaction to the samarium ion by the heart of the

frog on the one hand and of the mammals on the other, Niccolini can but exclaim, "Mistero per oggi impenetrabile, che ci fa meditare sulle meraviglie del Creato . . " This observation does at least suggest that should the rare earths function in any metabolic process, the possibility of considerable specificity should be entertained.

GALLIUM, INDIUM AND THALLIUM

These three elements were all discovered spectroscopically and are all relatively rare, though widely dispersed, components of the universe. Their cosmochemical and geochemical abundance is given by Goldschmidt as

	Ga	*In*	*Tl*
Meteorites: atoms per 100 atoms Si .	0.00084	0.000023	0.000015
Accessible lithosphere: atoms per 100 atoms Si.....	0.0022	0.0000071	0.000015
Accessible lithosphere: grams per metric ton.	15	0.1	0.3

Gallium in general follows aluminum, particularly in late crystallization products, the lattice radius of the tervalent ion Ga^{+++} being slightly greater (0.62Å) than that of the aluminum ion Al^{+++} (0.57Å). Gallium is, however, more easily reduced than is aluminum, and tends to enter the metallic phase of meteorites to some extent. It may therefore be presumed that part of the terrestrial supply has been lost to the metallic core; the relative enrichment of the accessible lithosphere is less great than in the case of aluminum.

Indium is markedly siderophil and in the lithosphere apparently shows no tendency to accumulate in the more accessible later products of crystallization. The element is thus somewhat rarer in terrestrial rocks than in meteorites. Thallium, while rarer than indium cosmically, in its univalent state tends to follow the heavier alkalies (Tl^{+} 1.49Å, Rb^{+} 1.49Å, K^{+} 1.33Å), and may be much enriched in leucites, micas, and potash feldspars. In the last-named minerals, cases have occasionally been reported of the presence of as much as 0.1 per cent thallium. This enrichment in late crystallizing rocks puts the cosmically rarer thallium in a better position than indium to play a biological rôle.

Little is known of the occurrence of any of the elements in the pedosphere. Robinson (1938) indicates the presence of gallium and thallium in soils, but states that indium is unrecorded. Hutchinson and Wollack (1943) found about 0.3 mg. of gallium per kilo. of dry surface soil from a Connecticut woodland; no quantitative data for thallium appear to exist.

Böttger (1863) recorded thallium from mineral waters and kelp and concluded that the element must exist in the ocean, but I. and W. Noddack (1940) were unable to detect thallium in sea water, in which the concentration cannot exceed 10 γ per cubic meter. The same investigators found 0.5 mg. gallium per cubic meter of sea water. The ratio of aluminum to gallium in the ocean is thus about 100:01, whereas in the lithosphere a ratio of 100:0.02 is found; some enrichment of the rarer element over the commoner therefore takes place in the sea. Gallium appears to occur in fresh waters but in smaller quantities than in sea water; in Linsley Pond, N. Branford, Conn., rather under 0.1 γ per litre seems to be present in the surface waters (Hutchinson, *unpublished observation*). No records of the occurrence of indium in the hydrosphere have been published.

The biogeochemistry and biological function of gallium

Indications of the existence of gallium in living organisms appears to have been published in only five papers. Cornec (1919) reported the element qualitatively from *Laminaria*, Vinogradov (1935b) doubtfully from an undetermined gorgonian. Vinogradov's (1935b) statement that Zvinden had found gallium in human tissue appears to be an erroneous citation. D. Bertrand (1941a), however, has found the element to be recognisable after chemical concentration in samples of human urine of diverse origins. I. and W. Noddack (1940) found gallium present in the series of nine animals that formed the material for their excellent spectrographic study of marine organisms, the amount varying from 0.1 mg. per kilo. dry in an eviscerated specimen of *Squalus acanthius* to 0.7 mg. per kilo. dry in the body wall of *Asteiras rubens* and *Bryssopsis lyrifer*. The mean quantity was 0.4 mg. per kilo. dry, which would correspond to about 0.07 mg. per kilo. of living matter. The mean concentration factor is therefore about 140, or probably considerably greater than that for aluminum. To the phyla examined by the Noddacks, namely the Porifera, Coelenterata, Echinodermata and Chordata (tunicate and fishes), may be added the Mollusca, for D. Bertrand found gallium qualitatively in European oysters.

Shear and Ussery (1940) could not detect gallium in tobacco and concluded the quantity present is less than 0.0001 per cent of the ash, which would correspond to 0.1 to 0.2 mg. per kilo. of the dry plant. D. Bertrand, however, gives qualitative records of gallium in tobacco and in strawberries.

Hutchinson and Wollack (1943) record in *Lycopodium flabelliforme* about 0.1 mg. per kilo. dry, or about 0.03 mg. per kilo. of living plant, and in *Mitchella repens* a quantity between 0.1 and 0.2 mg. per kilo. dry or 0.03–0.07 mg. per kilo of living plant. These figures, falling within the rather restricted range given by the Noddacks, suggest a relatively constant quantity of gallium, of the order of $n \times 10^{-6}$ per cent, in all organisms. *Lycopodium flabelliforme* absorbs gallium far less efficiently than aluminum; *Mitchella repens*, growing in the same mixed stand, takes up the two elements in about the proportions present in the soil. Both plants absorb iron far less efficiently than the other two elements, and also contrast strongly with the marine animals, which appear to take up gallium in preference to aluminum.

By the use of specially purified salts and organic nutrients in the preparation of culture media, Steinberg (1938, 1939a, b) has given apparently conclusive proof that a minute amount of gallium is needed for the normal growth and reproduction of *Aspergillus niger*, and more recently (1941) for *Lemna minor*, grown in sterile culture. Leonian and Lilly (1940) did not find any stimulation of *Phycomyces blakesleeanus* by gallium, but other well-established trace metals were equally ineffective, and they concluded that their negative results merely indicated that the quantity required was small compared with the amount of zinc needed by the fungus. Riley (1943) found the marine diatom *Nitschia closterium*, in nutrient-deficient media, is stimulated by gallium, but that in cultures enriched with nitrate and phosphate this effect disappeared. No experiments were done in which gallium alone was omitted from a complete nutrient solution giving optimal growth. Since traces of gallium are almost always found in the aluminum compounds of the biosphere, it is unlikely that any regions characterized by gallium deficiency exist, while the general low concentration of the element would exclude any ecological effects due to excess. As yet there are no indications of the nature of the function of gallium in plants, but in spite of the geochemical association of the element with aluminum, in many of its properties (gallous and gallic salts, $GaCl_3$ soluble in ether, complex cyanides) gallium resembles iron rather than aluminum, and might well play a part in metabolism, similar to that of iron but on a very restricted scale.

Indium has as yet never been recorded in any living organism, and apart from its occurrence in small amounts in certain coal ashes (Goldschmidt, 1937), the possibilities of its biogeochemical migration are entirely unknown. A paper by Siniakova (1940) on the polarigraphic determination of minute amounts of indium, however, indicates that the biological distribution of the element has been under investigation in Vernadsky's laboratory. So far, the results would appear to have been negative (Vinogradov 1943).

The biogeochemistry and biological function of thallium

Böttger (1863) recorded the element spectroscopically in beets, chickory, wine lees, beechwood, tobacco and kelp. The occurrence in *Beta* is confirmed by Breckpot (1936). Berg (1925) gives two determinations of 0.1 mg. thallium per 100 g. of fresh material in rye and spinach, but these data clearly refer to exceptional cases, which set an upper limit of 10^{-4} per cent to the thallium content of vegetation rather than a value for the mean concentration. Richards and Troutman (1940) find thallium generally detectible in the ash of yeast.

The only data available for animals are derived from the work of I. and W. Noddack, who found the following quantities of the element in marine invertebrates:

	mg. per kilo. dry
Cyanea capillata	0.03
Metridium dianthus	0.03
Stichopus tremulus	0.003
Asterias rubens	0.003
Bryssopsis lyrifer	0.001

No thallium occurred in the tunicate, sponge, or two fishes studied. The mean concentration for the whole series would be 0.007 mg. per kilo. dry or about 0.001 mg. per kilo. living matter. Since the thallium content of sea water is less than 10 γ per cubic meter, a concentration factor of the order of 100 or more is apparently indicated by these results.

It has long been known (Gottbrecht, 1880; Schulz, 1886) that minute amounts of thallium stimulate the

growth of yeast. Richards (1932) found that certain commercial samples of asparagin gave an abnormally low yield of yeast when used in the preparation of culture media. This was found to be due to an ash constituent present as a contaminant in the asparagin that gave a high yield. Microchemical and spectrographic studies indicated that the constituent was thallium. Addition of 1 γ of thallium acetate per millilitre of medium, made with the deficient asparagin, raised the yield by about 60 per cent, the growth being now as good as in the medium made with asparagin containing the contaminant ash constituent. These experiments strongly suggest that thallium plays a part in the normal metabolism of yeast.

The other biological studies of thallium are exclusively concerned with the toxicity of the element, and in general are not relevant to the present contribution. One supposed case of an ecological excess has been reported, namely the disease, characterized by the mottling and thickening of young leaves, known as "frenching" in tobacco. This condition is characteristic of certain soils and thallium treatment of experimental plants can produce symptoms that are very similar to "frenching" (McMurtrey, 1932) though according to the most recent investigations (Bortner and Karraker, 1940) they are not identical. Although it appears probable that "frenching" is due to a water-soluble material which in non-toxic amounts added to a non-toxic thallium solution results in a toxic solution (Spencer, 1935, 1937; Spencer and Lavin, 1939), it has proved impossible to detect thallium in "frenched" tobacco plants grown in the field without thallium (Shear and Ussery, 1940). The belief that the disease is an expression of an ecological excess of thallium is therefore apparently ill-founded.

The toxic action of thallium in animals is well known, particularly the alopecia induced by chronic thallium poisoning in mammals. Such a condition, though outside the scope of the present review, may be mentioned as indicating a considerable physiological specificity in the action of the element. The existence, moreover, of rock-forming minerals occasionally enriched in thallium may ultimately be found to result in locally endemic thallium accumulation in plants and consequent intoxication in animals. The use of thallium compounds as poisons in the control of small mammals may bring disaster to the natural population of predators, as is said to have occurred in the case of the Californian Condor.

(To be concluded)

NEW BIOLOGICAL BOOKS

The aim of this department is to give the reader brief indications of the character, the content, and the value of new books in the various fields of Biology. In addition there will frequently appear one longer critical review of a book of special significance. Authors and publishers of biological books should bear in mind that THE QUARTERLY REVIEW OF BIOLOGY *can notice in this department only such books as come to the office of the editor. The absence of a book, therefore, from the following and subsequent lists only means that we have not received it. All material for notice in this department should be addressed to B. H. Willier, Editor of* THE QUARTERLY REVIEW OF BIOLOGY, *Department of Biology, Homewood Campus, The Johns Hopkins University, Baltimore, Maryland, U. S. A.*

EMBRYOLOGIA CHEMICA VERA IN STATU NASCENDI

Being a review of *Biochemistry and Morphogenesis*, by Joseph Needham. *Cambridge* (The University Press); *New York* (The Macmillan Company), 1942. Pp. xvi + 787. 9¾ x 6½ inches. $12.50.

By Viktor Hamburger, Washington University, Saint Louis.

Five years ago the English edition of Spemann's book, *Embryonic Induction and Development*, appeared. It marks, in a sense, the end of the "classical" period in experimental embryology. It surveys largely Spemann's own experiments, and those of his collaborators; yet it is, at the same time, the most articulate expression of the contemporary approach to embryonic development. Theoretically the epigenetic concept of animal development which it upholds has become firmly entrenched in our minds. Methodologically a marked unity of purpose was accomplished by a self-imposed limitation. Problems, experiments and terminology were kept strictly within the range of the biological level. The interactions of living systems during development were analyzed, without taking recourse to the biochemical level, and in disregard of a semi-quantitative or mathematical treatment. (It is true that the chemical nature of inductors was discovered by experimental morphologists, and not by biochemists. Spemann posed the problem as early as 1925, and most of the pioneer work was done by Holtfreter. Yet it may be said that the main emphasis of these investigations was on the morphogenetic response rather than the nature of the mediators.) The requisite of the mind for causal explanation was satisfied by establishing causal relations within this realm of biological entities. This consistent attitude has given rise to many misgivings, misunderstandings, and controversies. Its accomplishments testify to its soundness.

Meanwhile, experimental embryology has reached a new stage in its life cycle. A new category of problems has arisen which originated in a new philosophical outlook. Needham's book, though deeply rooted in the tradition of Spemann's and Harrison's ways of thinking, marshals this new period. It prepares the ground by clarifying the issues and gathering material. The author's theoretical point of view has been expressed before, in his essays *Order and Life* (1936) and in his Herbert Spencer Lecture in 1937. It is restated with clarity in the present book: "We cannot but consider the universe a series of levels of organisation and complexity, ranging from the subatomic level, through the atom, the molecule, the colloidal particle, the living nucleus and cell, to the organ and the organism, the psychological and sociological entities" (p. xiv). "Organising relations are found at the molecular level, and at the colloidal and paracrystalline level . . . just as clearly as at the anatomical level" (p. 679). "Only in the light of the conception of integrative levels can the saecular gulf between morphology and chemistry be bridged" (p. xv). It is admitted that "the regularities discovered by experimental morphology will always have their validity and will, in a sense, be unaffected by anything which either biochemistry on the one hand or psychology on the other, may discover" (p. xv). "But the important point is that although the regularities established at the level of experimental morphology are rirefragable, they will, in the absence of biochemical experimentation, remain forever meaningless" (p. xv). For Spemann, these regularities were eminently meaningful; for Needham "Meaning can only be introduced into our knowledge of the external universe by the simultaneous prosecution of research at all the levels of complexity and organisation, for only in this way can we hope to understand how one is connected with the others" (p. xv).

It is obvious that at the present time, the synthesis of biochemistry and morphogenesis is a postulate and a challenge for biochemists and experimental embryologists, rather than a fulfillment. What can be done is to

collect the raw material and integrate it as far as possible. Needham is well equipped for such a task. His encyclopedic mastery of the literature is unique. Anybody who has consulted his *Chemical Embryology* knows that he is unrivalled in this respect. He draws freely from all corners of the biological universe, from experimental embryology, biochemistry, genetics, cancer research, endocrinology, general physiology. His bibliography includes approximately 6000 titles; the foreign literature is carefully covered, including publications which are not easily accessible. The list of references for the more important chapters of the book seems very nearly complete. In less important chapters where completeness is expressedly disclaimed, the author gives references for the most recent review articles.

It takes a person of Needham's constructive imagination to weld this enormous mass of data into a readable book. Fortunately, however, he did not succumb to the temptation of fitting the data into a uniform mold. Such an attempt at the present status of our knowledge would have been necessarily dogmatic and artificial. As a matter of fact, a direct biochemical attack on morphogenetic problems is in progress only with respect to the analysis of the inductor substances in Amphibian embryos, in the work of the Scandinavian school on sea urchin development, and in a few scattered investigations in developmental genetics. Most of the biochemical studies of the embryo are as yet more or less indirectly related to morphogenesis. The two main indirect avenues of approach are the chemistry of the materials which build up the embryo, and the study of metabolic and respiratory processes during development. Ultimately, they will merge, because inductors and gene products must be integral parts of metabolism. Without attempting an artificial unification, Needham is realistic enough to let the three stand singly, each on its own feet. Logically, then, the book is divided into three parts: I, The Morphogenetic Substratum (100 pages); II, The Morphogenetic Stimuli (400 pages); III, The Morphogenetic Mechanisms (200 pages). Parts I and III cover about the same ground as *Chemical Embryology* (1931); they bring this earlier book up to date by a review of the literature of the decade from 1931 to 1941. Part II is largely original. It gives extensive treatment to inductors in Amphibians, and is also a comprehensive review of the literature on embryonic induction in other vertebrates and invertebrates, with special emphasis on the agents which are the mediators of the inductive processes. In addition it includes chapters on "organisers and cancer", on "genes and organiser phenomena," on regeneration, metamorphosis, etc.

It is one of the merits of Needham's book that it stresses the theoretical issues. The following review will emphasize this aspect rather than discuss in detail the factual data, which would be an impossible task. Furthermore, it is not possible for any one reviewer to do equal justice to all parts of the book. My own interests are centered in the second part, and my review of the rest must be quite casual.

Part I. The Morphogenetic Substratum

The first chapter discusses the composition of the hen's egg and the properties of the vitelline membrane; it gives a brief survey of the effects which vitamins in the diet have on the development and hatchability of the embryo. Similar accounts are given of the chemical composition of the eggs of other vertebrates and invertebrates. The next chapter takes up a particularly interesting phase of embryonic adaptation: the dependence of different types of eggs on their environment. In the course of evolution the egg became increasingly emancipated from the environment; the process culminated in the closed-box ("cleiodic") type of egg (reptiles, birds) and reversed itself again in mammals. The remarkable adaptive changes in chemical mechanisms, such as water uptake, metabolism and excretion which are necessitated by the transition from aquatic to terrestrial habitat, are reviewed. The last chapter deals with embryonic nutrition, yolk utilization, the properties of the embryonic membranes of the chick and of the mammalian placenta, placental transmission, and the allantoic and amniotic fluids.

Part II. The Morphogenetic Stimuli

This section covers the classical field of experimental embryology, embryonic determination. It begins with a discourse on the "general concepts of causal morphology," such as "determination," "competence," "fields," etc. Their clarification is important in view of the rather confused state of terminology in this field. Unfortunately we cannot say that Needham contributes materially to the elucidation of these concepts. The term "determination" is logically traced back to Driesch. It is defined as "progressive restriction of possible fates or potencies" (p. 101). This definition is negative (is determination really a block, an inhibition?) and the vague term "potency" is not defined further. In fact, this term (without further specification) should be relegated to that most useful scrapheap of obsolete and ambiguous terms which the author has created at the end of the glossary. The term includes at least three entirely different things: self-differentiating potency, reaction potency (now called "competence") and inductive potency.

An acceptable translation of the much-used terms *ortsgemäss* and *herkunftsgemäss* is proposed: "neighborwise" for the former, and "selfwise" for the latter (p. 102). The term "morphogenetic stimulus" which is revived in the heading of this part of the book is traced back in its history to Herbst's "formative stimuli", but defined neither here nor in the glossary. Spemann's concept of the "hierarchy of organizers" is adopted. Spemann called the archenteron roof the "primary organizer," and the ones which appear later

the "secondary," "tertiary," etc., organizers. (For example, the optic vesicle as lens inductor would be a secondary organizer.) It would be better to restrict the term "organizer" to the living archenteron roof, and to call the higher-grade organizers, "inductors." Among the characteristics of the archenteron roof are its regulative properties and its highly complex effects which result in the induction of a whole secondary embryo. Needham himself stresses the difference between simple induction of a structure like neural tube, and complex induction of an integrated patterned organ ("evocation" and "individuation"). The term "organizer" should be applied to the latter aspect of induction only. The term "competence" is used in preference to "reaction potency," which seems justified particularly since the useful adjective "competent" can be derived from it. "Competence" is conceived as a state of unstable equilibrium; "determination" as the stepwise transformation into more stable states of equilibrium.

The much debated "field" concept is treated briefly in this part of the book. It is also defined in terms of instability; ambiguities in its usage are pointed out. The term is widely used in the book, in the combination "individuation field" which will be discussed later. The short essay on "the liquidation of the entelechy" reduces a complex theoretical problem to its bare essentials and resolves some of the artificial and real difficulties of the age-old mechanism-vitalisms controversy.

The central, and most important part of the book, is the discussion of Amphibian morphogenesis. The author gives an exhaustive and clear account of the entire field of organizer experimentation. It is carefully done and correct in historical and factual details. The experiments on respiration and metabolism of the gastrula, including the author's own contributions, are critically considered and linked with the morphogenetic data. Of interest are the speculations on the possible combinations of the evocator substance with proteins and polysaccharides which render it inactive in the upper lip and in other tissues, and on possible mechanisms of its liberation after invagination. This part is profusely illustrated with reproductions of original photographs, drawings and graphs. As is well known, a good deal of discussion and controversy has centered around the question of the chemical nature of the medullary plate inductor (the primary evocator substance). There has been no doubt that induction is mediated chemically, ever since Holtfreter (1933) and others showed that killed tissues can induce medullary plate and since, a year later, the Cambridge and the Freiburg schools simultaneously found that cell-free extracts have inductive capacity. The question is still open whether we are dealing with a simple, definite substance which is contained in the upper lip and liberated during and after invagination. The experiments of Needham and his co-workers have led him to the conviction that there is such a substance and that it is probably a sterol. The strongest argument which, however, has failed to convince me, is the extremely low concentration at which certain sterols are effective. Their minimal effective dose compares with that of other biologically active substances, such as vitamins, hormones and carcinogens. But in connection with this argument it should not be forgotten that other medullary plate inducing substances have not been subjected to a rigid quantitative test. At any rate, the controversial material is presented in an objective way. It is stated toward the end of the discussion that "neural inductions can be brought about by a wide variety of chemical fractions and pure or relatively pure substances. Which, if any, of these is identical with the primary evocator occurring in the dorsal blastopore lip, . . . is as yet an unanswered question" (p. 186). Needham's assumption that the "primary evocator" is a sterol leads to interesting speculations as to its possible relations to sex hormones, Vitamins A and D, and carcinogens, all of which are steroid compounds. A chart (p. 262) depicts the "overlapping domains of biological specificity" of these related compounds. For instance, certain carcinogens are at the same time "neurogens" (another new term for the primary evocator substance) and so are certain oestrogens. Therefore the fields of neurogens, oestrogens, and carcinogens overlap. Such a graphic presentation is certainly striking, but I hope the chart will not find its way into the textbooks until the steroid nature of the "neurogens" is definitely proved. Similar ideas were already set forth in *Order and Life*. They are pursued at length in the chapter on organizers and cancer. The immediate link between the two is the discovery of Waddington, Needham, and others, that a number of carcinogenic substances act as medullary plate inductors. This alone would not necessarily be significant because a large number of other substances do the same. But Needham tries to find other, more general relations between organized and malignant growth. He goes back to the distinction of "evocation" and "individuation." He considers organized growth or morphogenesis as the result of two component activities: evocation, or the stimulation of competent tissue to undergo a specific but not patterned differentiation, such as nerve tissue; and individuation, or pattern induction in a previously "evocated" structure. Malignant growth he considers as evocation without individuation, or in his words, "escape from the individuation field." At present very little is gained by this formulation, because the concepts "individuation" and "individuation field" themselves are still obscure. Altogether, one has the impression that the length of this chapter is not in proportion to the few facts which link, at present, morphogenetic experiments with cancer research.

The next chapter deals with regional differentiation. Spemann discovered regional differences in the inductive capacity of the archenteron roof which led to the distinction of "head organizer" and "trunk" or "tail organizer." These and a number of experiments by

Holtfreter, Hall, and others, are reviewed, demonstrating specifically different effects not only of the organizer regions but of different adult tissues as well. How cautious one must be with the interpretation of experiments of the latter type may be seen from the results of Chuang, who found that fresh adult newt liver induces both head, trunk and tail structures, whereas mouse kidney induced only head structures. Toivenen, who implanted alcohol-coagulated liver and kidney (from different vertebrates) found just the reverse, which both he and Needham fail to point out. It will be necessary to experiment on a much larger scale using different adult structures as inductors, before the assumption that they produce specifically different effects can be considered as established.

Once the main axis of the embryo is laid down by the "primary organizer", secondary and tertiary inductors come into play which block out and determine further details of organization. When a structure has become determined it may, in turn, become an inductor for another structure. For instance, the optic vesicle, once determined by anterior archenteron roof, becomes a secondary inductor for lens, the lens becomes a tertiary inductor for cornea. Needham gives a useful tabulation of "second and lower grade organiser effects" (p. 302), but discusses in detail only a few selected cases. The account of the lens induction with all its ramifications is excellent.

At this point I should like to discuss several theoretical issues which are of importance for the evaluation of Needham's book. They are most clearly exemplified in the two chapters reviewed above. Needham is inclined to assume that the different lower grade inductors produce each a specific chemical substance. This is consistent with his stand in the matter of the primary organizer. However, the experimental evidence for this assumption is very meager and altogether not too favorable for such a hypothesis. For instance, no lens inductions have been obtained as yet from substances liberated by dead eye cups, although it must be admitted that this experiment has been made only on a small scale. On the other hand, isolated lenses were obtained in the absence of optic cups by induction from salamander liver and heart. All we can conclude from this experiment is that lens evocation is mediated by a chemical substance which is either widely distributed or which can be substituted by any number of agents. Needham argues: "If they (adult tissues) contain the primary evocator why not the secondary ones also? The disinclination to postulate a considerable number of active substances is, I believe, misguided, for there is no lack of chemical compounds isolated from living tissues for which no function has ever been found or even suggested" (p. 299). This argument of the biochemist does not carry much weight in the eyes of the morphologist. I wonder if the search for specific evocator substances promises at present the most fruitful line of attack of the induction problem. If carried to the extreme it will certainly do more harm than good. Take for instance the case of the so-called "individuation." Needham makes ample use in his book of the distinction between "individuation" and "evocation." They are usually illustrated by the case of the induction of the central nervous system. Two components in its determination are distinguished: one, the determination of nervous structure or neural tube in general, called "evocation"; and the other the determination of its regional character, for example, forebrain, hindbrain, or spinal cord, called "individuation." Sometimes it seems that the terms "individuation" and "individuation field" are entirely restricted to the determination of the central nervous system (p. 685), which would be unfortunate because limb and ear, and other organ inductions certainly involve the same components of pattern formation. I do not wish to enter into a discussion of the merits of the term "individuation field." It seems to me that it is simply another refuge for those as yet unanalyzed components of the inductive process which make for wholeness and for pattern. Such terms are as useful, on the biological level, as the old "harmonious equipotential system." They will one day become unnecessary when our knowledge is advanced. But to invent a special type of hypothetical substance, which would be responsible for "individuation" in the same sense as the well-established evocator substance is responsible for "evocation," and even give it a name, "eidogen," certainly carries this concept too far. Take, as an example, the rôle of the host in induction processes. If trunk organizer is implanted at trunk level, it induces trunk structures; if it is implanted at head level, a secondary head results. It is legitimate to describe tentatively this host influence by stating that a "head-individuation field" exists which overrides the tendency of the transplant to induce trunk structures. It is likely that we are dealing with a complicated interplay of many factors and agents which will be difficult to analyze, but are amenable to analysis. To think of the host influence in terms of a "head-eidogen" substance means not to heed the sound advice which the author himself gives: "While it is convenient for purposes of discussion to speak of the individuation field, we must be careful that this concept is not used in such a way as to sterilize further research" (p. 278). I would suggest a more dynamic and more flexible working hypothesis for the analysis of induction. I would conceive of determination of a given structure as being brought about by the interaction of a multiplicity of agents carefully integrated in time and space. Some of these would reside within the system to be determined (they make up what is now called "competence"), others reside outside of it in the inductors. Any one of these agents is replaceable by others; no single one of these multiple factors would deserve the rank of "the specific" inductor. This is not the place to elaborate on this idea, but many puzzling experimental results are easier understood by this than by Needham's hypothesis. Among

other things, gradients, which find no place in Needham's book, would fit into my scheme. The almost complete omission of gradients both in Child's particular formulation, and in the more general form of diffusion or concentration gradients of substances, is hardly justified in a book of such wide scope. One of the few exceptions is the discussion of the double gradient system in Echinoderms which is thoroughly established by the Scandinavian school. Child's theory is disposed of in a half page, and the author's position in *Chemical Embryology* is merely reiterated (p. 605).

In this second part of the book is included a chapter on "Genes and organisers." The author takes a far-sighted attitude in the matter of integration of embryology and genetics. "Organisers must indeed be regarded to a large extent as the intermediary mechanisms between the gene equipment and the final form and properties of the developed animal. It is therefore important to know how genes and organisers are related in normal development" (p. 340). Several roads lead in this direction. In the first place, the experiments of Spemann and collaborators are reviewed in which it is shown, by means of heteroplastic and xenoplastic transplantations, that inductors can act across genetic boundaries. The next chapter, headed by the inadequate title "Genes and the later stages of individuation," deals with the experiments of Harrison, Twitty, and others, which give important information concerning the maintenance or adjustments of species specific growth rates of organs, when transplanted to hosts of a foreign species. The literature on the respective rôles of nucleus and cytoplasm in development is skilfully condensed. The work of Baltzer, Hadorn and coworkers on hybrids and hybrid-merogons in Urodeles is given deserved prominence. An entirely different approach to the problem "genes in development" is given by the analysis of lethal and semi-lethal genes. Again, only a small number of representative examples is selected, taken from *Drosophila*, chick and mammalian literature. The author emphasizes the important point that many phenotypic manifestations must be considered as the result of gene action on inductors; that faulty or suppressed inductor action must result in widely scattered morphological abnormalities; in other words, that many pleiotropic gene effects are secondary or indirect. Gene-produced hormones and diffusible substances are reviewed in a special chapter.

Of the other chapters in this section two deserve special mention: those on determination in insects, and in echinoderms, which give a concise and up-to-date summary. The chapter "Mosaic eggs," on the other hand is entirely inadequate and partly inaccurate. In fact, the term "mosaic eggs" should also have been buried in the grave-yard of obsolete terms. The definition "*mosaic eggs* are those in which this determination [of the main features] has taken place before fertilization and cleavage; *regulation eggs* are those in which this determination does not take place until about the time of gastrulation" (p. 131) is incorrect. Take, for instance, Echinoderm eggs as an example of the so-called "regulation" eggs, and Annelid and Mollusc eggs as an example of "mosaic" eggs. Both have definite "mosaic" features even before cleavage: a stratification of qualitatively different substances along the animal-vegetal axis. As a result, egg fragments of both types obtained by horizontal cuts before cleavage will give rise to fragmentary larvae, indicating "mosaic" development, whereas cutting along the main axis will result in "regulation" and subsequent formation of whole larvae from each half. Both types of eggs show therefore a strikingly similar degree of "determination" at this early stage. The same holds for the other representative of "regulation" eggs, the Amphibian eggs, in which the "marginal zone" (future organizer) is segregated shortly after fertilization. One of the main differences between the two "types" is in the rôle which cleavage plays in the sundering of these different substances. In Annelid and Mollusc eggs, and also in Ascidian eggs, it serves as a mechanism of segregation so that the blastomeres contain qualitatively different materials; in Echinoderms and Vertebrates, cleavage has nothing to do with the distribution of these morphogenetic agents. The author repeats a mistake which has become "classical" since Driesch made it when he interpreted his isolation experiments on sea urchins: to judge the state of determination of an egg by the outcome of isolation experiments of blastomeres.

Part III. The Morphogenetic Mechanisms

This part is a rather heterogeneous assembly of quite different topics. The main chapters deal with respiration and metabolism of the embryo. They are preceded by chapters on dissociability of fundamental morphogenetic processes and on "heterauxesis." A large amount of data is compiled to show that a number of well-defined partial processes such as growth, cell division, nuclear division, can be disengaged from each other experimentally. The yield of this information, as far as a deeper understanding of morphogenesis is concerned, is meager. One learns not much more than that there is considerable leeway in normal development. The chapter on heterogonic growth, now called "heterauxesis," is not intended to give a complete survey of this topic but is limited to the increase in amounts of chemical constituents. It culminates in what the author calls "the chemical ground plan of animal growth." He presents the growth curves for a number of chemical entities in different animals, and shows "that organisms of extremely different morphological form give identical differential growth ratios for a given chemical substance . . . Not "protoplasm" only, but also the changes which it undergoes in chemical constitution during the growth of the organism, would then be identical in all animals" (p. 558). This idea is later

on qualified with respect to individual specificity of protoplasm.

The chapter on respiration takes up in succession eggs and embryos of different groups. It reviews in sufficient detail recent work of Clowes and Krahl, Tyler, Bodine, Brachet, and many others; that of the author and of others on respiration of the Amphibian gastrula is taken up in the chapter on the organizer. The discussion of respiration in mammals includes that of anaerobiosis in embryonic life and the review of the work of Barcroft and collaborators. In the following part on metabolism, which was the main subject of *Chemical Embryology*, the respective chapters in that book are brought up to date. The author takes up in succession: carbohydrate metabolism, protein metabolism, nuclein metabolism, lipin and sterol metabolism, and adds a special chapter on pigment metabolism. Most of it is straight biochemistry of the embryo. The relation of the chemical changes during development to the morphological changes is yet to be established.

The last chapter of the book discusses, under the somewhat inadequate title "polarity" the submicroscopic, micellar and molecular structure of protoplasm and its possible relation to morphogenesis. In this topic, which promises to supply the most direct link between both levels of organization, our ignorance and the almost complete lack of valid information is most keenly felt. The modern literature abounds in good discussions of protoplasmic structure and its molecular and micellar basis. The review in this book is too brief to give an adequate picture. The few attempts to correlate data on fine structure with those from experimental embryology, for instance with Harrison's classical studies on axial determination in Urodele limbs, ears, etc., or with the process of neurulation, are premature. Entirely missing in Needham's discussion is any reference to the cell surface as a possible seat of morphogenetically significant events. The author rather envisages "that embryology may become largely the study of protein fibres and their planned distortion and orientation" (p. 673).

Altogether, this is one of the most stimulating books in the current biological literature. Thanks to the wealth of material incorporated in it, it is a valuable source of information for both embryologists and biochemists. The attempt to clarify theoretical issues, however, is not too successful. It is a very readable book, written in a lucid and personal style, and much more concise than *Chemical Embryology*. It is excellently illustrated. Many of the 328 figures are photographs from original experiments; most drawings are originals. The voluminous bibliography is condensed into a relatively small space (69 pages) by a technique of rigid abbreviations of the titles of periodicals. The reader pays for this economy with a slight inconvenience; he must consult constantly the key to the abbreviations of journals, unless he is an ingenious guesser. In addition to a glossary there is a list of "terms and concepts the use of which is not recommended."

I should like to suggest two technical improvements. First, the sources of origin are omitted in the legends of almost all figures, and not even the references in the text indicate them in every instance. It is desirable that acknowledgments of the authorship of all illustrations be added. Furthermore, it would enhance considerably the usefulness of the bibliography if each reference were annotated with the page, or pages, at which the author is quoted.

BRIEF NOTICES

EVOLUTION

STUDIES OF CENOZOIC VERTEBRATES OF WESTERN NORTH AMERICA AND OF FOSSIL PRIMATES. *Contributions to Paleontology. Carnegie Institution of Washington Publication 530.*

By Arthur B. Drescher, E. L. Furlong, Ida S. DeMay, Paul C. Henshaw, Robert W. Wilson, Hildegarde Howard, and G. H. R. von Koenigswald. Carnegie Institution of Washington. Washington, D. C. $2.25 (paper); $2.75 (cloth). 9¾ x 6⅞; 222 + 31 plates. 1942.

The first of these studies is by Drescher on the *Later Tertiary Equidae from Tejon Hills, California* (3 plates, 6 text figures). Recent collections from this area furnish sufficient evidence to permit reappraisal of earlier studies of the fossil horses of this region. Two groups of horses can now be defined, one from the lower, Santa Margarita, formation and the other from the overlying Chanac formation. Considerable data are added to the dentition records of *Nannippus tehonensis* (Merriam) from the Santa Margarita formation. From the Chanac formation is reported a new species of fossil horse, *Pliohippus leardi*. While no complete dental series of this species was found, a sufficient number of upper teeth were obtained to construct composite series.

The next paper—*A new Pliocene antelope from Mexico*, with remarks on some known antilocaprids (2 plates, 1 text figure) is by Furlong. The new genus, *Hexobelomeryx*, which is described, "shows an unusual type of specialization of its horn cores, in which three distinct prongs are present." Ida S. DeMay follows with two papers, the first, *Quaternary bird life of the McKittrick asphalt, California* (4 text figures), and the second, *Bird life on the Carpinteria asphalt, California* (4 text figures). DeMay finds that the great abundance of falcons, buteonid hawks, and small owls from the McKittrick "strongly suggests that there was considerable open country in the region about the tar seeps in late Pleistocene time. The presence of nesting quail, doves, and road runners indicates particularly

the presence of chaparral-covered hillsides in the vicinity." The Carpinteria assemblage substantiates the view that the Carpinteria asphalt traps were situated in a forested region. "Half of the species with known habitat preferences are those usually found in wooded areas, and more than a third have a preference for brushy regions. Of the six species represented by young birds as well as mature individuals, three are brush dwellers."

The fifth paper in the series, and by far the longest, is by Henshaw on *A Tertiary mammalian fauna from the San Antonio Mountains near Tonopah, Nevada* (11 plates, 7 text figures). The presence of a saline lake and plains fauna give evidence of an arid climate for this region. That the bones were not widely scattered and occurred in delta deposits along the shores of the lake further bears out the theory of the occurrence of occasional droughts. The mammalian fauna contains 19 species, 6 of which are known from no other locality. "The abundance of grazing horses (*Merychippus*) and antelopes, coupled with the occurrence of camels and long-limbed rhinoceroses, indicates without question that the environment was one of grassy, perhaps shrub-covered plains." The Equidae make up the bulk of the fossil remains. Teeth and foot bones are in great abundance but only a few and poorly preserved vertebrae are found and no complete skulls. Two distinct groups are represented, the hypohippine (10 adult and 2 young) and the merychippine (100 adult and 10 young). Many of the systematic descriptions of the forms are accompanied by detailed dentition measurements, and where limb bones were available, measurements of these are given.

The next paper is by Wilson on *A preliminary study of the fauna of Rampart Cave, Arizona* (4 plates, 1 text figure). The importance of this cave first became known in 1936. Two test pits have been dug in the floor of the cave which is composed of ground-sloth dung. These pits yielded a wealth of vertebrate fossils. Wilson gives a preliminary survey of this material which is in the collections of the museum in the National Park Service headquarters at Boulder Dam. For the present no further excavations at Rampart Cave will be undertaken. In the seventh paper Hildegarde Howard gives *A review of the American fossil storks* (1 plate, 2 text figures), while in the eighth and last paper, *The South African man-apes and Pithecanthropus*, von Koenigswald discusses the evidences which "demonstrate beyond any doubt that *Pithecanthropus* is a member of the human family."

UPPER CRETACEOUS FLORAS OF THE ROCKY MOUNTAIN REGION. *Contributions to Paleontology, Carnegie Institution of Washington Publication 508.*

By Erling Dorf. Carnegie Institution, Washington. $3.00 (cloth); $2.50 (paper). 11½ x 9; 168 + 36 plates; 1942.

This report is in two parts: (I) Stratigraphy and Palaeontology of the Fox Hills and Lower Medicine Bow Formations of Southern Wyoming and Northwestern Colorado (19 plates, 8 text figures); (II) Flora of the Lance Formation at Its Type Locality, Niobrara County, Wyoming (17 plates, 3 text figures).

In the first part Dorf outlines the stratigraphy and palaeontology of the Medicine Bow formation and describes and discusses the fossil plants collected within the past two years from this formation. Collections were made from six localities, and for each of these regions detailed information is given concerning exact location and areal distribution of formations (with accompanying maps), position of faunas, floras, and coal beds (illustrated by measured sections), and complete lists of fossil plants found. There is also given in chart form changes in interpretation of the stratigraphic sequence beginning with 1907, when the earliest geological studies of the region were made, to the present time when Dorf gives his own interpretation.

A total of 64 recognizable forms is reported of which 47 are referred to as species previously described by others, 11 are described as new species, and 6 are recorded as not specifically determinable. They are distributed as follows: Dicotyledonae, 45 species; Monocotyledonae, 8 species; Coniferales, 2 species; Equisetales, 1 species; Filicales, 3 species; and 5 species whose position is uncertain. Three localities furnished a sufficient number of specimens for quantitative leaf counts to be made. These showed the most abundant leaves to be those of *Ficus planicostata*. A study of leaf character (margin, length, nervation, texture, organization, dripping point) showed that the Medicine Bow flora "is distinctly not a cool temperate assemblage, but is intermediate in character between warm temperate and subtropical, more nearly approaching the latter."

In the second part of the study the author limits his report "to the description and discussion of plants known definitely to have come from the Lance formation at its type locality." Earlier work in the area is reviewed, the stratigraphy outlined, fossil plants listed for each locality and the composition of the flora discussed. Seventy forms are reported, falling among 32 families as follows: Dicotyledonae, 55 species; Monocotyledonae, 6 species; Coniferales, 2 species; Ginkgoales, 1 species; Lycopodiales, 1 species; Equisetales, 1 species; Filicales, 4 species. Of these, 56 forms are referred to species previously known, 5 are described as new species, and 9 are given generic designation but are not specifically determinable. Quantitative analysis was not particularly satisfactory since none of the localities in the Lance Creek area yielded more than 280 specimens. An analysis of leaf characters and a comparison of the generic and specific fossil and living forms of the region point to humid lowland conditions

of growth under a warm temperate to subtropical climate, more nearly approaching the former.

"For purposes of correlation the Lance formation at its type locality is made the basis of a new provincial time term, 'Lancian age.' This time unit is regarded, on the basis of the stratigraphic position and palaeontology of the type Lance formation, as latest Cretaceous, i.e., post-Montanan and pre-Paleocene."

In both parts of the monograph the systematic descriptions of the fossil forms are accompanied by very fine plates. The work concludes with an index of genera and species.

GENETICS

SYSTEMATICS AND THE ORIGIN OF SPECIES *from the Viewpoint of a Zoologist.*

By Ernst Mayr. Columbia University Press, New York. $4.00. 9 x 5¾; xiv + 334; 1943.

In this book, Mayr has made an excellent and very lucid synthesis of the contributions of modern systematics to the problem of speciation. The book is based on studies of the systematics of birds though studies of other groups are treated more briefly. This emphasis on one group has the disadvantage that it leads at times to somewhat one-sided conclusions with which students of other groups might not agree. However, it has the distinct advantage that the conclusions are based on one of the taxonomically best studied groups.

The book is written from the point of view of the so-called "new systematics" in which the emphasis is on infraspecific variation and the evolution of species as opposed to the so-called "old systematics" in which emphasis is more frequently placed on the identification and cataloging of species. Mayr points out that this point of view has been applied primarily in investigations of well-known groups and that of necessity it has been little applied in poorly known groups. It is most successful in groups in which most of the species are already known.

A discussion of the origin of species is necessarily greatly influenced by the species concept employed. Mayr employs a "biological" species concept. He states: "Species are groups of actually or potentially interbreeding natural populations, which are reproductively isolated from other such groups." This definition has the advantage that it is based on a characteristic, reproductive isolation, which is fundamentally involved in the process of speciation rather than on morphological or other characteristics which might be considered more as biproducts of the process. However, as Mayr points out, it is not always easy to use in practice and as a consequence it must often be left to the judgment of the taxonomist whether reproductive isolation has really been established. While Mayr realizes this, it seems to the reviewer that he has not taken it sufficiently into account in some of his discussions of individual cases.

With such a definition, morphological difference is no longer a sufficient criterion for species delimitation. As a consequence, different populations of the same species may differ morphologically from one another. Mayr points out the value of such a polytypic species concept in simplifying taxonomy. He shows the considerable reduction in the number of recognized species, particularly monotypic species, that has come about in recent years through the application of this concept.

Mayr devotes considerable space to geographic variation. He discusses in some detail various phenomena such as *Rassenkreise*, etc. Great stress is laid on geographic isolation as a first step in speciation. Mayr is inclined to believe that other kinds of isolating factors play little rôle in these first steps, at least in animals. However, he points out that no final conclusion can be reached in this matter. It seems to the reviewer that cases of adaptive radiation in lakes and other isolated areas present serious difficulties for this point of view despite the fact that Mayr points out that some of them can be explained on the basis of original geographic isolation.

In one of the longest chapters, Mayr discusses "The biology of speciation". Special emphasis is laid on various isolating mechanisms that may serve to separate one species from another. Here, as elsewhere, no detailed discussion of genetic mechanisms is given since these have been discussed in other works. However, Mayr shows that he is thoroughly familiar with the contributions of modern genetics to the study of evolution.

The final chapter discusses rather briefly the higher categories of classification. Mayr concludes that these higher categories are, unlike species, primarily subjective units though they are based on the objective fact that all species are not equally distinct from one another. A discussion is also given of the various factors involved in macroevolution and the way in which these factors can be used to explain various macroevolutionary phenomena. This discussion shows that it is at least theoretically possible to explain macroevolution in the same terms as microevolution.

The book is very clearly and logically written. This, together with the author's obvious familiarity with fields of biology other than his own, should make this work of great value in bringing about a better understanding of the contributions of systematics to evolutionary theory and in facilitating the synthesis of the results of different lines of investigation into a unified and logical picture. It should be read by all who are interested in the problems of evolution.

ANIMAL BREEDING PLANS.

By Jay L. Lush. Iowa State College Press, Ames, Iowa. $3.50. 9¼ x 6¾; viii+437; 1943.

The study of animal husbandry has been substantially elevated and clarified by the appearance of this excellent text. In a precise and authentic manner, the author has discussed the origin, genetics, and the merits and possibilities of the various accepted procedures of improvement of the races of domestic animals (including fur-bearing animals, bees and silk-worms).

After a brief analysis of the history of animal breeding methods and the mendelian mechanism of inheritance, the genetic basis of variation is discussed in the light of modern statistical procedure. The balance of the volume is devoted to the consideration of methods available for the improvement of animal stocks, namely, selection, inbreeding, and outbreeding, and carefully points out the merits and faults of each method in relation to the improvement desired.

The author makes a plea for animal breeders to set up a definite plan of procedure concomitant with a definite goal (e.g. improved body appearance for show work, improved body size and flesh texture for meat production, improved physiological attributes for the production of superior quality and quantity of wool, milk, eggs, etc.), before attempting to improve the race or strain of animals. The recommended plan is (1) to decide what type or kind of animal is nearest the ideal for a given characteristic; (2) to find which animals have the most perfect hereditary record with respect to the desired qualities; (3) to get the animals that most nearly meet the phenotypic and genotypic ideals for a given trait and set them to reproducing at rates proportional to their perfection of heredity; and (4) to hold on to, and closely line-breed the most perfect individuals obtained. Time, patience, and careful selection and breeding are indicated as equally important ingredients in the success of any attempted program of animal improvement.

Each chapter carries a list of references pertinent to the discussions presented therein, as well as numerous formulae and tabular material. A short index is provided.

GENETICS FOR MEDICAL STUDENTS.

By E. B. Ford. Methuen and Company, London. 7s. 6d. 7¼ x 4¾; 162; 1942.

Of all textbooks of genetics, Ford's *Genetics for Medical Students* is probably the one that follows least a traditional cliché. Only too often a textbook of genetics has been a juxtaposition of independent chapters. Ford's new book makes of the principles of genetics a coherent story, in which the different aspects of genetics are bound together by a well thought through *plan d'ensemble.*

The book is a response to the growing demand for genetic knowledge among medical students and physicians. This no doubt has helped the author in selecting the method of presentation and the material. The latter again is rather unusual: to make the book more attractive to the particular type of reader for whom it has been written, the examples illustrating the basic principles of genetics have been selected, so far as possible, among the material of human genetics. Even Mendel's first and second laws are illustrated by crosses involving human characters. Significantly the index contains only nine references to *Drosophila* and none to maize. Not only examples from man are preferably selected, but throughout the book emphasis is placed on the facts and methods of particular importance for the study of human genetics.

The book is divided into six chapters: I. Mendelian heredity; II. The genetics of sex; III. Mutation and the nature of heredity; IV. The action of the genes; V. Polymorphism; VI. Methods of study in human genetics. A basic knowledge of cytology is assumed: consequently the usual description of the "physical basis of heredity" will not be found in the book, except in the form of a condensed summary, in an appendix. A second appendix provides the reader with a classified list of some human genes.

The book will hardly be regarded as a full-fledged textbook. To fulfill that function it is too short, too poorly illustrated, somewhat too general and lacks the traditional list of problems which proves so useful in the teaching of genetics. It is to be considered rather as an introduction to a more detailed study of human genetics and as such it will undoubtedly be successful.

FAMILY TREASURES. *A Study of the Inheritance of Normal Characteristics in Man.*

By David D. Whitney. Jaques Cattell Press, Lancaster, Pa. $3.50. 9¾ x 6¾; 299; 1942.

The author has attempted to write a popular account of human inheritance based primarily on normal variations. To do this he has made use of a large collection of photographs, often of several generations of a family. The text is built around these photographs.

Unfortunately the text does not live up to the excellence of the figures. Whitney has attempted to dispel superstitious beliefs concerning birthmarks, maternal impressions, etc.; but he has substituted in their place another kind of superstition. Anyone reading his book without previous acquaintance with genetics would certainly come to the conclusion that any characteristic found in more than one member of a family is thereby shown to be inherited. Whitney makes no distinction between characters whose inheritance has been clearly shown and those whose inheritance is doubtful or improbable. For example he makes the statement that good taste in dress is inherited and

presents four photographs to illustrate it. Whitney does not state how he evaluated this ability, but it is to be doubted that everyone would agree that his choice of photographs was completely fortunate. This absolutely uncritical, frequently naive, attitude characterizes the whole book. There is nothing that would give the reader a satisfactory idea of even the most elementary genetic principles or of the careful methods so essential in the study of human inheritance. There is certainly no excuse for such a completely uncritical, indeed misleading, book. It is highly unfortunate that this important subject has been presented to the general reader in this way.

GENERAL BIOLOGY

THE OCEANS: *Their Physics, Chemistry, and General Biology.*

By H. V. Sverdrup, Martin W. Johnson, and Richard H. Fleming. Prentice-Hall, Inc., New York. $10.00; Text edition, $8.00. 9 x 6; x + 1077 + 8 folding charts; 1942.

This volume, by three staff members of the world's leading institution for oceanographic study, is the most comprehensive treatise ever compiled dealing with this subject. Some years ago when the senior author was lecturing before the American Association for the Advancement of Science the chairman who introduced him stated that he would speak about the biggest thing in the world—the ocean. A book dealing with such a subject cannot help but be bulky, and this volume will disappoint no one in this respect. There is a certain type of mind to which the statement that the foreign circulation of this book has been prohibited by the Federal Government will be more impressive than the differential equations that are so generously scattered throughout its pages. It is true that it makes a definite contribution to the war effort, but to attempt its appraisal on that basis would be a most inappropriate way to evaluate its importance, for its contribution to the arts of peace is even more significant. Long before the present holocaust became inevitable the experimentation and observation on which the book is based was under way. It is the fruit of the pursuit of truth—of a sincere search for knowledge of what goes on in that little understood domain beneath the surface of the sea.

Throughout the ages man has stood in awe before the sea. The land he could subdue and survey, he could even remove mountains if he had adequate faith, but the sea defied him wherever he encountered it. Homer thought it was a river that flowed around the world; Pytheas and Leif Ericson ploughed its uncharted surface on their way to discover new lands, in ignorance of what lay beneath their keels; Jules Verne speculated about it and wrote one of the most remarkable novels of all time; and Anton Rubenstein dedicated to it the lengthiest symphony in musical literature; but the combined knowledge of all of these is not so great as that which an intelligent reader might glean from a careful perusal of this book. Not that any such reader will have an easy task; the book is frankly intended for the trained specialist, but many of its less esoteric passages shed light on those questions which inevitably arise in the mind of anyone who has stood

> "gazing with a timid glance
> On the ocean's broad expanse."

It is now universally believed that life originated in the ocean. Not only does sea water resist sudden changes in temperature, salinity, and alkalinity, but it holds in solution all those substances which enter into the chemical composition of living matter. In fact, the chemical content of sea water is practically identical with that of the body fluids of marine animals generally, and has the same osmotic pressure. It is also so similar to the blood of the terrestrial animals as to lead to the belief that the latter represents the condition of the sea water at the time when the ancestors of the terrestrial animals first emerged from the ocean to seek a new life on the land.

The most influential factors in the distribution of plants and animals in the ocean are light and temperature, respectively. Below the level to which sunlight can penetrate there can be no photosynthesis, and consequently no vegetable life except that of the anaerobic bacteria. An excellent illustration of this is the Black Sea, which is more than 2000 meters deep. The Straits of the Bosphorus are only 40 meters in depth, and this effectively precludes the entrance of oxygenated water from the Mediterranean. The only water that the Black Sea receives is mostly from the Danube and Don rivers, so that aeration by convection currents is reduced to a minimum and what little oxygen there may be is exhausted by the decomposition of organic matter accumulated on the bottom, and the lower 1800 meters is so highly toxic that it cannot support animal life of any kind.

The depth to which light can penetrate is approximately the level of the continental shelf, so there can be no vegetable life on the continental slope. But ocean currents and the vertical displacement of water from other causes brings sufficient oxygen to the slope to support animal life which subsists on the continuous precipitation of planktonic material from the surface layers of the sea.

The phytoplanktonic forms have a specific gravity slightly greater than that of sea water, and mostly have no power of locomotion, so that they are always descending to the depths. The rate of this descent into the abyss is very slow—due in part to the friction between the water and the surface area of the organism. Although the phytoplankton consists of extremely minute organisms, the surface areas of these forms are quite large in proportion to their weight. In certain

local areas there is an upwelling of water from the depths, and this is frequently sufficient to overcome the sinking tendency, otherwise the phytoplankton might have been exterminated long ago.

It is well known that animals living in the darkness of subterranean caverns tend to lose their eyes and their pigmentation. But the nektonic forms from below the limit of light penetration generally are heavily pigmented and have well-developed eyes. This unexpected condition seems to be related to the presence of luminescent organs which are of common occurrence among abyssal forms but unknown in cave fauna. That such luminescence is ever strong enough to reveal non-luminescent organisms by reflected light, however, seems unlikely.

There is a great difference between the animal and vegetable kingdoms as to the number of their phyletic groups represented in the marine flora and fauna. Of the seventeen phyla of animals five are exclusively marine and none lacks marine representation. But with one strange exception all marine plants are algae. The one exception is the eel grass, a true flowering plant whose root is attached near mean low water level. At high tide the eel grass is entirely submerged.

The reviewer puts down this book rather reluctantly, regretting that lack of space precludes more than mere mention here of such matters as the tides, ocean currents, distribution of temperature and salinity, plankton, the Sargasso Sea, sedimentation, Globigerina ooze, coral reefs, inter-relations of organisms, etc., to mention a few at random. The science of oceanography is still young, and our knowledge of many special phases of it has been acquired during the most recent years. What we know today about it is but a drop in the bucket (or shall we say, in the ocean?) as compared to what we have still to learn. The sea is still the symbol of the mystery, and the increments of our knowledge about it are like islands, surrounded by the unknown. As we complete the survey of each island we realize more completely the meaning of Rosetti's words "Leagues beyond those lands there is more sea."

BIOLOGY SEASON BY SEASON *for Catholic Schools.*
By Sister Mary Anthony Payne. American Book Company, New York. $2.32. 8¼ x 5¼; xi + 675; 1942.

"The beautiful quotation from the Book of Genesis gives us a reasonable and acceptable explanation of the origin of matter, form, and life—vegetative life, animal life, and rational life."

Thus, fully armed and substantially supported by the Bible (wonderful document that it is) the author presents a somewhat biased picture of biology for the consumption of high school students of the Catholic faith. It is true that the volume is unique in organization, and based upon sound pedagogical principles (the materials are arranged so that the student will be studying the various biological forms and interesting biological processes during that part of the year with which they are most logically identified), but it is unique also in the reticence and ambiguity with which such topics as sex, reproduction, and evolution are presented. Of course, no other theory on the origin of life and matter is given except the one quoted above.

Except for the above limitations, the biological principles expounded are essentially sound, the illustrations adequate, though at times irrelevant (e.g. p. 492), and the overall bearing of the text is acceptable. In spite of the handicap of biased selection and presentation of subject matter, the careful student should be able to obtain a working knowledge of biology from these pages.

A complete glossary and index are appended.

HUMAN BIOLOGY

TABOO: *A Sociological Study.*
By Hutton Webster. Stanford University Press, Stanford; Oxford University Press, London. $4.00. 9 x 6; xii + 393; 1942.

Webster gives the following definition of taboo: "Taboos are prohibitions which when violated, produce automatically in the offender a state of ritual disability—'taboo sickness'—only relieved, when relief is possible, by a ceremony of purification." On this basis he describes briefly hundreds of taboos concerning the reproductive life (menstruation, pregnancy, birth, miscarriage, twins); concerning the separation of sexes in eating, work and worship; and those taboos concerning sexual intercourse, common, premartial, adulterous and incestuous. He collects the taboos concerning death and the dead, widows and killers, the taboos concerning strangers and strange phenomena, sacred things and persons. He eventually discusses the economic aspects of taboo (tabooing of property, certain foods and seasons, etc.). It is obvious that among these hundreds of cases it may be questioned whether some really belong in the field outlined by the author's definition of taboo. It is clear too that even such a very extensive study is not and cannot be "complete" in listing *all* the relevant cases out of a really gigantic ethnographic literature.

Webster neither discusses the existing theories of taboo (Frazer, Marett, Freud, Wundt, Lehmann, etc.), nor has he one of his own. But one has the definite impression that, in spite of recognizing positive by-products of taboos, to him taboos are mere superstitions. This is not surprising as Webster's present book as well as the *Primitive Secret Societies* (1908) and *Rest Days* (1916) use the same technique as the famous "comparative" books of Frazer, Westermarck, Sumner-Keller, and Crawley, which in their approach were fundamentally rationalistic and evolutionistic. Mod-

ern anthropology is very far from this technique and approach, but for the rapid survey of a field, for reference purposes, these books as well as Hasting's *Encyclopedia of Religion and Ethics* are still valuable storehouses of knowledge. Here lies also the main strength of this book, all the more as Webster has also very conscientiously gone through the extensive and brilliant field work of the last 30–40 years, which was not available to any of his predecessors.

From Webster's survey one gains the impression that the situations most apt to produce taboos are those of death and sex life—two not only socially decisive, but also eminently biological situations. It is thus not surprising that among these taboos, essentially social institutions, we find a good many which present a challenge to the biologist for further research: e.g. the case of tribes where taboos admit sexual intercourse exclusively during the menstruation period, or the perplexing cases where death and sickness are not only explained but *actually produced* by taboo transgression.

MAN'S POOR RELATIONS.

By Ernest Hooton. Doubleday, Doran and Company, New York. $5.00. 9 x 6½; xl + 412; 1942.

The term "man's poor relations", as used by the author, embraces the lemurs, tarsiers, New World monkeys, Old World monkeys, and anthropoid apes. These animals, together with man, comprise the mammalian order Primates. The title of this book might well have seemed appropriate in the lush nineteen-twenties; but to-day one is inclined to wonder wherein these so-called "lower primates" are "poor"—unless it be in that cerebral deficiency that denies them the blessings of civilization and the luxury of total world war.

Despite the seeming impropriety of its title, let it be said at once that this book is one for which all biologists should be grateful. They should be especially grateful to Hooton for having compressed into 400 pages—and in a most felicitous manner—a fair share of the existing knowledge of primates other than man. The scientific literature that treats of these animals is truly vast, and the author's task has been Gargantuan.

Nearly one half of the book (176 pages) is devoted to the anthropoid apes, 55 pages to the monkeys of the Old World, 42 pages to those of the New World, 9 pages to the tarsiers, and 35 pages to the lemurs. This unequal treatment to a large extent is a measure of our knowledge of the several primate groups. The closing section of the book (62 pages) is strictly comparative, dealing with selected topics—social organization, blood, brain, skeletal proportions, and teeth.

The volume, however, does not attempt to be all-embracing, for some subjects receive either scant mention or even none at all, whereas others are dealt with at lengths that may appear disproportionate. Obviously the author has made no effort to be truly comprehensive in his treatment of the subject, but has been guided chiefly by his own fancy. Thus the psychological aspect of primates, dealing with social behavior and the like, covers many pages; while the treatment of morphology is sketchy and unbalanced. The professional student of primates will encounter a number of errors in the text, but none of these are of a major character. Considering the task to which the author has set himself, they are in fact remarkably inconsiderable.

Hooton has produced a unique book, written in his customary lively and attractive manner. For this reason, but also for its intrinsic worth and usefulness, it will recommend itself to all persons interested in man the animal.

YALE UNIVERSITY PUBLICATIONS IN ANTHROPOLOGY. *No. 25; The Ciboney Culture of Cayo Redondo, Cuba*, by Cornelius Osgood; *No. 26; Archeology of the Maniabon Hills, Cuba*, by Irving Rouse.

Yale University Press, New Haven; Oxford University Press, London. $3.50. 9¾ x 7; No. 25, 65 + 6 plates; No. 26, 184 + 8 plates + 1 folding map; 1942 (paper).

This publication is a result of the collaboration between the Caribbean Program of the Yale Peabody Museum and the Institute of Andean Research.

Osgood has excavated a midden on Cayo Redondo, a small island in a mangrove swamp bordering the Bay of Guadiana on the north coast of the Peninsula of Guanahacabibes, which comprises the western-most extremity of Cuba. He found mostly shell and stone implements; shell gouges (peculiar for Cuba); shell cups; stone hammer grinders, as they are found all over the West Indies and in the adjacent parts of North and South America; stone picks and the wide-spread stoneballs (of ceremonial use?).

The findings on Cayo Redondo make part of a nearly unitary culture. In their simplicity they seem to emanate from "Ciboney" people, as archeologists now call the non-pottery people which preceded the Arawak and Caribs in the West Indies.

The study by Rouse is a survey of the previous research in the Maniabon Hills in eastern Cuba. The publication of Rouse's own work in the Maniabon Hills is still deferred. The author gives a succinct and very interesting survey of the history of Cuba and especially the Maniabon Hills, insofar as the Indian population is concerned. He gives a detailed study of archeological exploration in the Maniabon Hills which since 1860 has been rather extensive. He describes 190 sites, also artifacts not allocated according to site. Of the sites, 14 are "Ciboney" while the overwhelming majority

(113) is "Sub-Taino" (Arawak). The "Sub-Taino" sites are divided into 74 villages, 8 camps, and 39 caves. They contain mostly pottery, but also implements made from stone, bone, and shell. The relationships of Maniabon culture with surrounding areas (Haiti, far eastern Cuba, southern and western Cuba) is discussed. Rouse's synthesis of very much dispersed material will be of the highest value to all those who are interested in American archeology.

YOUNG OFFENDERS: *An Enquiry into Juvenile Delinquency.*

By A. M. Carr-Saunders, Hermann Mannheim and E. C. Rhodes. Cambridge, at the University Press. $1.75. 7¼ x 4¾; x + 168; 1942.

It is readily observed that there is likely to be an increase in juvenile delinquency during and immediately after a war. But it is difficult to make a convincing investigation of delinquency at such times because appropriations for activities that do not contribute directly to the war effort are likely to be drastically curtailed to the point of inefficiency. In the present instance it was found impossible to assemble sufficient information about delinquent girls to justify their inclusion in the present investigation.

The outstanding conclusion that can be drawn from a study of delinquent boys in London and seven other English towns is that a boy from a broken home is about six times as likely to become delinquent as one from a normal home, and it makes little difference in the delinquency rate whether the home was broken by death or divorce, or whether the parents were unmarried.

The age at which most children become delinquent is thirteen. Now it so happens that the number of thirteen-year-old children in England at the time these statistics were compiled was significantly greater than it would have been had the birth rate been constant over a period of years. But the authors have devised a technique which takes into consideration the population of the various age groups as a whole so that it is not possible to attribute the high incidence of delinquency at this age to the fluctuating birth rate.

Another fact brought out by this investigation is that children who are active in school, church, or club are less likely to become delinquent than those who are not.

The book is well written, and contains a lengthy summary of all previous investigations of delinquency. We need more published reports of this sort, and larger appropriations to make them possible.

THE NATIVE TRIBES OF EASTERN BOLIVIA AND WESTERN MATTO GROSSO. *Smithsonian Institution, Bureau of American Ethnology Bulletin 134.*

By Alfred Métraux. Smithsonian Institution, Washington, D. C. 35 cents. 9⅛ x 5⅞; 182 + 5 plates; 1942 (paper).

Métraux who has himself done important field work in South America, has collected in this little volume the essential facts known about two score of tribes living in Eastern Bolivia and Western Matto Grosso, that is, in the very heart of the South American continent. Such a survey will be all the more welcome as most of the sources (going back partly to the Spanish conquest) are not written in English and are difficult of access. In spite of the fact that Métraux had to build on very incomplete foundations, the book gives a wealth of very important data, especially in the field of material culture—agriculture, hunting and fishing techniques, road-building, curare preparation, construction of musical instruments, etc. The study is historical and comparative, but Métraux fortunately avoids the complete dissolution of culture organisms into isolated "traits", characteristic of the still valuable study of the late Erland Nordenskiöld on the same region (*The Ethnography of South America seen from Mojos in Bolivia;* Comparat. Ethn. Studies 3; *Göteborg*, 1924). A very good bibliography is given, but unfortunately no index, which would be very desirable in view of the many synonymous tribal names. The reviewer feels also that a short geographico-historical introduction would greatly improve the excellent little book, especially if it would eventually help in answering the problem of depopulation of this region, which, oddly enough, all investigators mention but so far no one has attempted to explain.

THE JAPANESE. *Smithsonian Institution War Background Studies, Number Seven: Publication 3702.*

By John F. Embree. Smithsonian Institution, Washington, D. C. Free. 9 x 6; iv + 42; 1943 (paper).

The people of Japan have suddenly forced themselves upon the attention of a nation whose citizens have known little or nothing of them in the past, or have generally regarded them as quaint Gilbert and Sullivan folk in *kimono* who could never really learn how to fly an airplane. We have learned to our dismay the error of this attitude. In the pages of this little book, a brief account is given of the beginnings and present social structure of the Japanese nation. It is readily demonstrated that there is nothing "mysteriously oriental" about the Japanese. Like other human beings, their thoughts and acts are conditioned by early training and cultural environment, and the better these are understood, the better the behavior of the people may be understood and predicted. Because the author feels that most people are already familiar with them, descriptions of material culture, such as house types and clothing, have been largely ignored in this background study. The same applies to descriptive ac-

counts of Japanese art and literature. Instead, emphasis is laid on the social and historical aspects of Japanese culture which are at once unfamiliar to Occidentals and of special importance in determining Japanese attitudes and behavior. Material here discussed is divided into six main sections: origins, national social structure, family and household, cycle of life, religion, and concluding remarks on cultural homogeneity and borrowing, and popular misconceptions regarding the Japanese. The series of sixteen excellently-reproduced plates greatly assist the average reader in his interpretation and understanding of the subject matter presented. The appendix gives interesting facts and figures about the Japanese and their empire. There is a list of references and a selected bibliography, but no index. This little volume is of especial significance at the present time and is heartily recommended to all.

POLYNESIANS; *Explorers of the Pacific. Smithsonian Institution War Background Studies, Number Six: Publication 3701.*

By J. E. Weckler, Jr. Smithsonian Institution, Washington, D. C. Free. 9 x 6; 77 + 20 plates; 1943 (paper).

The Polynesians, who were the first human inhabitants of the farflung mid-Pacific islands, were the most daring deep-sea voyagers and explorers the world has ever known. In the double-hulled ships they fashioned with stone tools, they sailed by easy stages across the widest part of the unknown Pacific, from southeastern Asia probably all the way to the coast of Peru. They did this centuries before Columbus ventured into the Atlantic, even before the intrepid Vikings found their way gradually across the north Atlantic to the New World. The area discovered and populated by these seafarers is known as the Polynesian triangle. The word Polynesia itself means "many islands." The present account gives, in a clear and fascinating fashion, the remarkable story of these inhabitants of the mid-Pacific region. We are told about the ancient homeland from which the Polynesians probably came, their shipbuilding and seafaring activities, the new lands which they explored and settled, the beginnings of their religion and mythology, the great period of colonization, Polynesian ways of life, the coming of the Europeans, and life in Polynesia today. The many excellent plates offer illustrative material of a very high order and add immensely to the text for the average reader. There is a selected bibliography but no index. The appendix gives pertinent facts about the main island groups in Polynesia. The material here presented in so lucid and entertaining a manner is of special interest at the present time in view of the daily war happenings in the Pacific theater of operations.

SIAM—LAND OF FREE MEN. *Smithsonian Institution War Background Studies, Number Eight.*

By H. G. Deignan. Smithsonian Institution, Washington. Free. 9¼ x 6¼; 18; 1943 (paper).

Siam—or Thailand as it is more properly called—is another country which has loomed large on the horizon in the present world conflict and one about which Americans in general have only meager and often misleading information. The present excellent account is an attempt to remedy this situation. The author discusses, in order: geography of the country, peoples, prehistory of the Siamese, and the kingdoms of Sukhothai-Sawankhalok, Aynthia, Tonburi, and Siam. The book concludes with an interesting discussion of present-day (that is, pre-World War II) Thailand. The author states that "a lively resistance to the present Japanese usurpers continues inside Thailand and through her spokesmen abroad." He further believes that "we may confidently expect that the Thai, with the aid and sympathy of their friends of the United Nations, will at the earliest opportunity rid themselves both of their quislings and their Japanese overlords." This is certainly encouraging speculation and it is hoped that the author's predictions come true.

The series of eight photographic plates, depicting scenes in modern-day Thailand are well chosen and serve a very useful purpose in illustrating the author's interesting and instructive presentation of the facts concerning this far-off "land of free men." There is neither bibliography nor index. To all who would become familiar with the background of the present conflict, this little book is an essential article for reading.

YUROK NARRATIVES. *University of California Publications in American Archaeology and Ethnology, Volume 35, No. 9.*

By Robert Spott and A. L. Kroeber. University of of California Press, Berkeley and Los Angeles. $1.25. 10¼ x 6¾, 143–256 + 1 map; 1942 (paper).

This is a collaboration between two authors, both of whom are well qualified for the task. Robert Spott is a well-educated Yurok Indian, both in the practices and traditions of his own people and in those of the white man as well. The narratives are set down just as he told them to Kroeber, who has added comments of his own. In the introduction Kroeber states that some of the narratives are history, some mythology, and some, perhaps the most interesting of all, are a blend of both.

The temptation is to compare this work with *Sun Chief*, also the product of cooperation between an Indian and a white man, reviewed in these pages some months ago. But the two books are not parallel. *Sun Chief* is an autobiography and the writer has endeavored to conceal the culture and folklore of his people. He discusses these matters only in order to

contradict the statements of an earlier writer. Robert Spott, on the other hand, is actuated by a desire to keep alive the traditions of his people; there is nothing in his contribution that is in any way autobiographical.

The reader who endeavors to read between the lines is likely to conclude that different Indians react differently to the impact of white civilization.

RAFINESQUE MEMORIAL PAPERS, *October 31, 1940. Transylvania College Bulletin, Volume XV, No. 7.*

By Francis W. Pennell, Alfred Emerson and Others. Transylvania College, Lexington, Ky. 9 x 6; 108; 1942 (paper).

In October, 1940, Transylvania College held commemorative exercises to mark the centennial of the death of Constantine Rafinesque (b. Constantinople, 1783 and d. Philadelphia, 1840), who for 6 years (1819–1825) served as Professor of Botany and Natural History (and for a time as Librarian) in that, at the time, young institution. The lectures presented at these meetings are here published. In the first, and longest, paper entitled "The Life and Work of Rafinesque," F. W. Fennell has succeeded in covering in an interesting manner and as briefly as possible a wide field, both of geography and of endeavor. Rafinesque not only travelled widely but his interests were in many directions and he wrote on everything that interested him, whether it was botany, zoology, ichthyology, herpetology, archaeology, philology, economics or poetry. Fennell was fortunate in finding some hitherto unpublished material in the form of letters, daybooks of expenses and manuscripts from which he draws in an effort to shed new light on the private and public life of Rafinesque. The other, briefer, papers (some published in abstract only) deal with Rafinesque's contributions to the archeology of the United States east of the Mississippi, the biology of fishes, herpetology and medicinal plants. A list of publications by Rafinesque which have been deposited in the Transylvania Library is appended.

CULTURE ELEMENT DISTRIBUTIONS: XXI. *Round Valley. Anthropological Records, Volume 8, No. 1.*

By Frank Essene. University of California Press, Berkeley and Los Angeles. $1.00. 11 x 8½; 97 + 1 map; 1942 (paper).

CULTURE ELEMENT DISTRIBUTIONS; XXII. *Plateau. Anthropological Records, Volume 8, No. 2.*

By Verne F. Ray. University of California Press, Berkeley. $1.75. 11 x 8½; iii + 99–258; 1942 (paper).

These are some of the last culture element distribution lists which have been collected during recent years under the direction of Kroeber. The series will furnish the basis for a synthetic study of the Californian Indian such as it has never been possible to do for any group of Indians hitherto—although we were already fortunate in possessing Kroeber's fine *Handbook of the Californian Indian.*

Essene lists and compares 2174 traits among the Lassik, Yuki, Kato, and Kalekau. He gives some interesting supplementary material concerning the Kato and Lassik.

Ray compares the occurrence of 7633 traits among the Wenatchi, Kittitas, Sanpoil, Lower Chinook, Klikitat, Kalispel, Lillooet, Chilcotin, Shuswap, Lower Carrier, Kutinai, Flathead, Coeur d'Alene, Umatilla, Tenino, and Lower Thompson.

HEADHUNTING IN THE SOLOMON ISLANDS *around the Coral Sea.*

By Caroline Mytinger. The Macmillan Company, New York. $3.00. 8¾ x 5⅝; ix + 416 + 8 plates; 1942.

This is an entertaining account of a pre-war trip to the south-western Pacific by two young American women "headhunting" for portraits of primitive natives, particularly Melanesians. Judging by the few, well-reproduced samples of her paintings and by her numerous facile sketches scattered through the text, the author is a most capable artist who has admirably succeeded in recording the characteristic figures and expressions of her exotic subjects. The many difficulties and hardships connected with transportation and accomodation to and in the Solomon Islands are vividly and humorously described. To induce aborigines to pose for their portraits required enormous patience and ingenuity.

To all those who now are eager to learn what life in Guadalcanal is like this book can be highly recommended as giving a frank and detailed picture from the layman's point of view. The biologist, however, will find disappointingly little of scientific value in the volume besides the beautiful portraits of the natives.

TEXTILE PERIODS IN ANCIENT PERU: II. *Paracas Caverns and the Grand Necropolis. University of California Publications in American Archaeology and Ethnology, Volume 39, No. 2.*

By Lila M. O'Neale. University of California Press, Berkeley and Los Angeles. 75 cents. 10¾ x 6¾ 143–202 + 5 plates; 1942 (paper).

This analysis of textiles from two Paracas sites in Peru provides additional evidence for a similarity in technique between the Necropolis collections and the weavings from Early-period Ica and Nazca Valley sites. The Caverns collection, on the other hand, exhibits a thorough knowledge of certain processes less charac-

teristic of other early sites. Neither the gauzes nor the fabrications distinguish the textiles of any site studied up to this time to the same degree as those from the Caverns; this culture may therefore be the earliest yet known for ancient Peru.

ZOÖLOGY

INTRODUCTION TO THE STUDY OF ANIMAL PARASITES AND PARASITISM.

By William A. Riley. Burgess Publishing Company, Minneapolis. $1.50. 11 x 8½; 87; 1942 (paper).

This is not a textbook, but a syllabus that has developed from information furnished to the author's students at the University of Minnesota. Its major purpose is to serve as a guide for introducing the student to the field of parasitology.

Although human parasitology is emphasized, many of those parasites of domestic and wild animals are discussed that occasionally establish themselves in the human host. Most of the information presented concerns the biological aspects of the parasites. The morphology and life history of the various species are very adequately presented while the medical phases of the diseases produced in the hosts are considered in less detail. After a chapter on the general phenomena of animal parasitism, the species of protozoa, helminths, and arthopods of major interest to the parasitologist are discussed in the order of their systematic classification. Some consideration is given to three groups of parasites whose taxonomic positions have not been definitely determined: bartonella, toxoplasma, and spirocheata.

Throughout the syllabus there are frequent references to the original literature; and at the beginning of each section, the student's attention is called to portions of comprehensive textbooks dealing with the subject to be discussed. The last few pages of the book are devoted to lists of standard textbooks, periodicals, abstract journals, indexes, and important papers on parasitology or closely related subjects. There are no figures or plates which would not be a serious disadvantage if the student has ready access to the references cited by the author. A table of contents is included but there is no index of the subject matter. One of the practical features of the volume is the way in which it is printed and bound. Each sheet is printed on only one surface and the book has a spiral binding which facilitates the making of notes and drawings.

THE ROSEATE SPOONBILL. *Research Report Number 2 of the National Audubon Society.*

By Robert Porter Allen. National Audubon Society, New York. $2.50. 10½ x 7¾; 142; 1942 (paper).

This is the second of a series of research reports sponsored by the National Audubon Society on rare and vanishing bird life. Between 1850 and 1890 the major destruction of spoonbills by man occurred in Texas and Florida, their numbers being reduced at the turn of the century to three small colonies. Since 1920, these handsome birds have recovered in Texas, but in Florida their occurrence is still sporadic. It appears that invasions from further south have been responsible for their return to the United States, although their exact source is still unknown.

Intensive studies by the writer show that the species is limited in its distribution to suitable nesting and roosting areas, with adjacent shallow waters containing an abundant supply of food, mainly small fish. Man is no longer regarded as a decisive destructive agent and predators are influential only in certain localities.

Observations on the mating behavior indicate that the females influence the males and that releasers are present in both sexes. A territory is defended but this area becomes progressively smaller as incubation begins. In a mixed colony of birds, the spoonbill is at the bottom of the peck order, although no serious rivalry is encountered. The incubation period is around 23 to 24 days, and the average clutch is 2.7 eggs per nest. Data are presented on food and feeding habits. There is a thorough discussion on plumages, the fully adult breeding plumage not being attained until 33 to 36 months. By recognizing these plumages it was ascertained that the Florida birds are mostly immature and hence non-breeders. No definite evidence was found to explain why the Texas colonies have been so successful in re-establishing themselves while the Florida birds have not bred to any appreciable extent.

There is still much to be learned concerning the biological needs and the limiting factors of the species, but this study makes a timely and valuable contribution.

THE BED-BUG: *Its Habits and Life History and How to Deal with It. Fifth Edition. British Museum (Natural History) Economics Series No. 5.*

By A. W. McKenny-Hughes and C. G. Johnson. Trustees of the British Museum, London. 6d. 8½ x 5½; 20 + 1 plate; 1942 (paper).

The Mediterranean seaboard seems most likely to have been the primary center of distribution of the bed-bug. In England bed-bugs apparently were first found in the ports, early in the 16th century. Now-a-days bed-bugs are not only found in all ports throughout the world but they are widely distributed in all countries. In England war conditions—large groups of people flocking to air-raid shelters, and large scale evacuations of the population—have resulted in a much wider distribution of this pest in all parts of the country than was formerly the case.

This little pamphlet has been prepared for the layman

and gives brief descriptions of the species of bed-bug occurring in Great Britain, distribution, sucking apparatus, life-history, habits and biology, dissemination, where to look for bed-bugs, and bed-bugs and disease. While the bed-bug is not the carrier of disease such as influenza, scarlet fever, measles, and the like, the authors state that in

> infested areas it is often possible to pick out children from buggy homes by their pasty faces, listless appearance and general lack of energy. It can be argued that the house in which bugs are tolerated will also be the home of malnutrition, dirt and other causes of physical infirmity. Such causes cannot be held solely responsible, and sleepless nights with constant irritation due to the injection of the minute doses of Bed-Bug saliva into the blood are likely to contribute largely to the ill health of children and even of certain adults.

Considerable space is devoted to the control of the bed-bug, especially by fumigation. The illustrations, including one colored plate, have been well chosen and carefully executed.

LARVAE OF DECAPOD CRUSTACEA. *Volume I (No. 129 of the Series) Issued to Subscribers of the Ray Society for the Year 1941.*

By Robert Gurney. Ray Society, London. 25s. 9 x 6; vi + 288; 1942 (paper).

The larval forms of aquatic Crustacea have always been difficult to study and because of their variety of forms, have caused considerable confusion as to their identity. This volume presents the significant discoveries made in this field up to the present and thereby is an invaluable contribution to a subject beset by many complex problems.

Following an historical introduction on Decapod larvae, the writer emphasizes their importance on classification. He maintains, in contradistinction to Ortmann, that the larval stages do give pertinent clues to the phylogeny of the group. For instance, it is suggested that the Copepoda have arisen by arrested development from a larval form having the general characters of the Decapod protozoea. Other topics discussed are dimorphism, rate of growth, locomotion, poecilogony, distribution, eggs, and egg bearing. The various anatomical regions are reviewed, especially that of the appendages.

The second part of this volume is descriptive, wherein the various larval stages of all the major groups of the Decapoda are described. In the majority of cases the examples are illustrated and tables express the gill formulae and the construction of appendages in comparative fashion. There is a bibliography and an index, the former being a supplement to a previous contribution by the same author entitled *Bibliography of the Larvae of Decapod Crustacea*, published by the Ray Society in 1939.

GENERAL ZOOLOGY.

By Tracy I. Storer. McGraw-Hill Book Company, New York and London. $3.75. 8⅛ x 6; xii + 798. 1943.

Storer's *General Zoology* is an excellent text. It combines a wealth of subject matter and numerous excellent figures with such a flexible plan of arrangement that it should be adaptable to almost any college course in zoology. The book is divided into two parts. The first part stresses general principles with vertebrates (man and frog) as the main examples, though invertebrates are also considered. This part starts with a general introduction followed by a chapter on the frog as a typical animal. This is followed by chapters on Protoplasm, cells and tissues; Organs and organ systems; Reproduction and development; Heredity and genetics; Animal ecology; Distribution of animals; Organic evolution; History of zoology; and Classification and nomenclature.

In the second part each phylum is discussed separately in some detail. The chordates are treated with special fullness, nine out of the twenty-two chapters in this part being devoted to this phylum.

While the book is in general excellent, one criticism might be made. In some places, too much material is presented in too condensed a form. It would have been better to have omitted this material than to have put it in a form in which it would mean little or nothing to most students.

There is an index and a rather complete glossary. Lists of references are given at the end of each chapter.

GUIDE TO THE LITERATURE OF THE ZOOLOGICAL SCIENCES.

By Roger C. Smith. Burgess Publishing Company, Minneapolis. $2.00. 10¾ x 8¼; vii + 128; 1942 (paper).

This manual is a volume which is difficult to classify exactly. It is the outgrowth of an outline used for many years at the Kansas State College of Agriculture in a course dealing with zoological literature and its uses, but it has been expanded so as to become at least partially independent of other class work. The material is arranged in outline form and almost every conceivable topic related to the zoological literature, from how to pick a satisfactory thesis problem to lists of the world's largest libraries, is mentioned.

Various sections deal with the mechanics of library classification, abstract journals, bibliographies of the zoological sciences, taxonomic indexes and literature, the preparation of a scientific paper, etc., etc. Quite extensive lists of biological journals with short notes on the material which they contain are included, but these are not complete and unfortunately do not include journals published in the Soviet Union, about which American biologists in general have the least available

information. In most of the sections the examples given are chosen from the fields of entomology and taxonomy and other fields appear to be much less completely considered.

The main value of this volume will undoubtedly be as a classroom aid in courses dealing with this subject. It contains a tremendous amount of varied information, but its form of presentation and lack of completeness in most fields will make it less desirable as a reference work.

THE RING-NECK SNAKES, GENUS DIADOPHIS. *Bulletin of the Chicago Academy of Sciences, Volume 7, No. 1.*

By Frank Nelson Blanchard. Chicago Academy of Sciences, Chicago. $1.25. 9½ x 6¼; 144; 1942 (paper).

This monumental work was compiled by the late Professor Blanchard over a period of 20 years, but since it had been completed only as far as the manuscript stage at the time of his death in 1937, the editing and publishing was left to a former student, H. K. Gloyd. The latter has done a superb job of presenting the material in accordance with the plan of the original author, and with a minimum of editorial changes and interpolations.

Data have been presented covering the description, habitat, distribution, variations and affinities of four different species and 14 subspecies of ring-neck snakes of the genus *Diadophis*. Both field and museum specimens have been used for studying the variations in size and color of body, the number of teeth, the number and arrangement of scales in distinguishing species, subspecies and geographic varieties. Each subspecies is introduced with a short bibliography on taxonomy. The monograph is concluded with a general bibliography of some 150 titles, and a short index. A helpful chart indicating probable species relationships is included.

THE CRAYFISHES OF FLORIDA. *University of Florida Publication; Biological Science Series, Volume III, No. 2.*

By Horton H. Hobbs, Jr. University of Florida, Tallahassee. $2.25. 10 x 7; 179 + 24 plates; 1942 (paper).

Ten years of intensive field observation, collection, and museum study have gone into this extensive report on the crayfishes of Florida. The discussions relating to the 42 species of crayfish native to Florida, are concerned not only with taxonomy, but with methods of collecting, preserving, and studying crayfishes, the ecology of the form, the distribution, migration and possible evolutionary trends in the development of present day species.

The author concurs with numerous other investigators in taxonomy, in pointing out that certain regions of Florida are unique in their fauna and flora. The Apalachicola River valley in Liberty and Gadsden counties, for instance, represents the southernmost limits of distribution of numerous plants and animals of the Appalachian and Piedmont regions, and many organisms of that river valley, including the crayfishes, show closer affinities to northern forms than to the native Florida stocks.

The report is well documented and indexed, and carries some 25 plates illustrating characteristic sex and species differences in anatomy.

FISHES OF THE PHOENIX AND SAMOAN ISLANDS COLLECTED IN 1939 DURING THE EXPEDITION OF THE U. S. S. "BUSHNELL". *Smithsonian Institution, United States National Museum Bulletin 180.*

By Leonard P. Schultz. Government Printing Office, Washington, D. C. 65 cents. 9½ x 5⅞; x + 316; 1942 (paper).

The author of this report was signed aboard the U.S.S. Bushnell as naturalist during the 1939 Navy Surveying Expedition in the Phoenix and Samoan Islands, and he had the opportunity to spend 16 weeks collecting and preserving representative fauna (especially fishes) of that region. The collection of fishes herein described represents the largest single ichthyological contribution to the National Museum since 1902, and includes some 14,000 specimens representing 30 new species and subspecies and 6 new genera distributed among 18 families. The discussion of each new species includes a detailed description of the form, the distribution insofar as it is known, and the affinities to previously described forms.

From the abundance of new forms represented in the present collection, the author concludes that the piscifauna of the South Pacific Ocean must be much more extensive than anyone now realizes.

A 20-page index is provided.

INTRODUCTION TO APPLIED ENTOMOLOGY. *Second Edition.*

By W. J. Baerg. Burgess Publishing Company, Minneapolis. $2.25. 11 x 8½; 146; 1942 (paper).

The first edition of this work was organized for use in the author's classes in economic entomology at the University of Arkansas, but its popularity and usefulness spread so rapidly to other schools that a revised edition for wider distribution and use became inevitable.

Data on a great variety of insect pests and related arthropods have been carefully selected, organized and illustrated for the purpose of bringing to beginning students in a logical and condensed form, the fundamentals of entomology as related to the welfare of man-

kind. The textual material of the volume is arranged by order and family of insect, and includes pertinent information regarding the habits and life history of each form, as well as the most successful control measures, natural or otherwise. A list of references is appended to the section on each insect, and a helpful index is provided.

THE ECOLOGY OF THE ORTHOPTERA AND DERMAPTERA OF THE GEORGE RESERVE, MICHIGAN. *Miscellaneous Publications, Museum of Zoology, University of Michigan, No. 54.*

By Irving J. Cantrall. University of Michigan Press, Ann Arbor. $1.50. 10 x 6¾; 182 + 10 plates + 2 maps; 1943 (paper).

Intensive collecting of restricted groups within a relatively small, well-defined area, contributes valuable information on the ecology and life history of the animals or plants in question. The nature of this study reveals the distribution of Orthoptera (and one species of Dermaptera) within three major ecological habitats, which in turn have been subdivided into 12 minor types. As would be expected, some species are limited very locally, others are widely distributed. Graphs portray the seasonal distribution of the species, three peaks of abundance being noticeable during the year. Other notes on the breeding habits, song, and behavior are incorporated in the annotated list.

THE MUSCULATURE OF THE LABRUM, LABIUM, AND PHARYNGEAL REGION OF ADULT AND IMMATURE COLEOPTERA. *Smithsonian Miscellaneous Collections, Volume 103, No. 7. (Publication 3697).*

By Carl Kester Dorsey. Smithsonian Institution, Washington, D. C. 30 cents. 9⅛ x 6⅛; 42 + 24 plates; 1943 (paper).

The results of a comparative study of the muscle arrangement in certain regions of the insect head and stomadaeum are presented in this paper. The investigation was undertaken to determine the nature of the complete act of the ingestion of food by the chewing insect. The facts presented indicate, however, that the cibarial, pharyngeal, and hypopharyngeal muscles play an important part in ingestion. The action of these muscles is undoubtedly supplemented by that of the labial muscles to a varied degree depending on the species. One half of this paper is devoted to illustrations of the musculature as worked out.

UNIVERSITY OF CALIFORNIA PUBLICATIONS IN ZOOLOGY. *Vol. 46, No. 6. The Nature of the Red, Yellow, and Orange Pigments in Woodpeckers of the Genus Colaptes,* by Frederick H. Test.

University of California Press, Berkeley. 25 cents. 10¼ x 6¾; 19; 1942 (paper).

UNIVERSITY OF CALIFORNIA PUBLICATIONS IN ZOOLOGY. *Vol. 51, No. 1. The Mechanism of Amphibian Gastrulation. I. Gastrulation-Promoting Interactions between Various Regions of an Anuran Egg (Hyla regilla), by A.* Mandel Schechtman.

University of California Press, Berkeley. 50 cents. 10¼ x 6¾; 40 + 1 plate; 1942 (paper).

UNIVERSITY OF CALIFORNIA PUBLICATIONS IN ZOOLOGY. *Vol. 51, No. 2. Differentiation and Growth of Gastrular Anlagen Implanted Homoplastically into Tadpoles of Hyla regilla,* by Morgan Harris.

University of California Press, Berkeley. 75 cents. 10¼ x 6¾; 45 + 5 plates; 1942 (paper).

THE NEARCTIC SPECIES OF PARASITIC FLIES BELONGING TO ZENILLIA AND ALLIED GENERA. *Proceedings of the United States National Museum, Volume 93. (No. 3157.)*

By Wendell F. Sellers. Smithsonian Institution, Washington, D. C. 9¾ x 6; 108; 1943 (paper).

BOTANY

AQUATIC PHYCOMYCETES *Exclusive of the Saprolegniaceae and Pythium.*

By Frederick K. Sparrow, Jr. University of Michigan Press, Ann Arbor: Oxford University Press, London. $5.00. 9¼ x 6; xix + 785; 1943.

To the general reader, a technical monograph such as this may well seem exceedingly dull, lacking in the glamor surrounding comets, miraculous drugs, and the sex life of primitive peoples. Even to biologists, the greater appeal of physiology has so far overshadowed the older and more basic taxonomy that most botanists have a somewhat derogatory attitude toward this branch of their science. Perhaps for this very reason, competent monographs are now sorely needed, and few groups are more in need of adequate treatment than the aquatic Phycomycetes, especially the large and complicated group of the Chytrids. This book, therefore, renders a great service to biology, for it is a monograph in the best sense of the term, using all possible lines of evidence for attaining a better classification of these organisms, and covering the structure, development, and reproduction with commendable thoroughness. To biologists, limnologists, botanists, algologists and mycologists, the appearance of Sparrow's book is an exciting and significant event.

The preface outlines the book's purpose, to meet the need of a comprehensive monograph of the Phycomycetes of fresh and marine waters, a need which the mass of material rapidly accumulating since von Minden's definitive survey in 1915 has made increasingly urgent, and limits the scope by excluding the Saprolegniaceae

and the genus *Pythium*, both of which have been monographed fairly recently. It outlines also the plan of organization of the book, notes the difficulties in attaining its objective of consistency in diagnoses of genera and species, and in giving precise geographic localities, and acknowledges the help of those who have aided in various ways.

The introduction, in 20 pages, effectively covers certain general preliminary matters, taking up first the nature of aquatic fungi in general and more specifically the characteristics of the primarily aquatic series of the Phycomycetes. A restrained and conservative discussion of the phylogeny and relationship of these organisms follows, noting previous speculations and theories, and emphasizing the basic soundness of Scherffel's interpretation of their phylogeny and his recognition of two series, the uniflagellate Chytridineen and the biflagellate Saprolegniineen-Peronosporineen. It briefly touches also on the occurrence of the different orders in relation to substrata or hosts and to fresh or marine habitats, and shows that our present evidence indicates the group is probably ubiquitous and world-wide in distribution. Especially valuable are the four and one-half pages on methods of collection, giving in detail the procedures which the writer and other specialists have found most successful, and supporting the general conclusion that the previously supposed rarity of these organisms has in reality been the result of a lack of knowledge of proper methods of collection. Equally valuable are the six pages on the methods of isolation and culture, emphasizing the techniques used by Couch, Stanier, and others in the Chytridiales, Emerson and others in the Blastocladiales, noting differences between the orders such as the Saprolegniales, of which practically all have been cultured successfully, and the Lagenidiales, which for the most part have not yet been brought into pure culture. A brief discussion of the most useful methods of preserving and mounting material follows, and finally the orders are arranged in a key on the basis of the flagellation of the zoospores and of the characteristics of the thallus and reproduction.

The detailed monographic treatment which forms the body of this volume takes up, one by one, the three orders of the Uniflagellate series and the five orders of the Biflagellate series. The Chytridiales, as is necessary for so notably large and difficult an assemblage, receives the most extensive treatment—370 pages. This starts with the historic background and early work in the group, gives the basis for previous and present taxonomic treatments, and outlines the distribution, occurrence, and salient characteristics of the order. The discussion of the morphology and development of the group (40 pages) is notably able, covering the thallus types and structure, non-sexual and sexual reproduction, and cytology, in a masterly presentation based on the author's own expert knowledge of the group, and his thorough familiarity with the difficult and voluminous literature. This general treatment ends with a discussion of parasitism, covering epidemics in nature and the conditions influencing them, and such interesting matters as host specificity and the effect of the parasite on the host cell, the mechanisms or factors controlling resistance of various algae, and hyperparasitism. The remainder of the section is devoted to the systematic account which presents first the characterization of the order, followed by a key to the families, after which each of the 7 families of the Inoperculatae and the two families of the Operculatae is taken up, characterized, and keyed to its genera, each genus being characterized and illustrated, while for each species a detailed diagnosis is given with pertinent information on its morphology, reproduction, behavior, relationship, parasitism, and other features. This section on the Chytridiales, by far the most complete and effective monograph of the order that has yet appeared, would even by itself stand as a major contribution to mycology.

Similar detailed treatment is given each of the remaining orders but these, being smaller and less complicated, naturally require somewhat less space. The 52 page discussion of the Blastocladiales is of special interest since the rapid expansion of our knowledge of this order in recent years and the growing appreciation of its biological significance have been exciting advances in mycology. The chapter on the Monoblepharidales, amplifying and extending Sparrow's own previous monograph of 1933, includes recent work on his remarkable and phylogenetically significant new genus, *Monoblepharella*.

At the end of this Uniflagellate Series, the family Hypochytriaceae, of doubtful position because of its anteriorly uniflagellate zoospores, is discussed briefly, with diagnoses and pertinent information on the species of the three genera it comprises.

Of the Biflagellata, the order Plasmodiophorales is covered in a chapter of 24 pages, wholly adequate for evaluating these forms in relation to others of this series, but necessarily less extensive than Karling's recent monograph of 144, 2-column pages which appeared almost simultaneously with the present volume. The chapter on the Saprolegniales, following the plan outlined in the preface, limits itself to covering the Ectrogellaceae and Thraustochytriaceae, leaving the Saprolegniaceae to the monographic treatment of Coker and of Coker and Matthews. That on the Leptomitales, here recognized as an order and separated into the two families, Leptomitaceae and Rhipidiaceae, brings up to date the work on this order since Kanouse's survey of 1927. The treatment of the order Lagenidiales is especially welcome, since in its 88 pages the author clarifies the content and position of this hitherto misinterpreted and troublesome group, separating it from the Chytridiales, with which it had been confused because of similar gross morphology, parasitism and habitat, and affording each member the adequate

treatment it merits. Completing the survey of the Biflagellata the chapter on the Pythiaceae of the Peronosporales confines itself to the genera *Zoophagus*, *Pythiogeton*, and *Pythiomorpha*, since the aquatic species of *Pythium* itself have already been treated by Matthew and others.

The list of substrata is well worth the long, discouraging work it must have entailed, for in 13 pages it presents the most complete and effective listing of the hosts or substrata and the aquatic fungi on them that has yet been compiled. The organization follows the taxonomic categories of substrata, beginning with plants, under which the algae are considered by classes, the species being listed alphabetically with the fungus or fungi inhabiting it following after a colon. From this organization one gains a quantitative idea of the relative frequency of occurrence of these fungi on algal groups, those on the Myxophyceae, for example, occupying but a quarter of a page, while those on the Chlorophyceae in general occupy two and one-half pages, on the Zygnematales over a page, and on the Desmids a page. Similarly, in the series of the Golden Algae, there are very few listings under Chrysophyceae, Cryptophyceae, and Dinophyceae, but over a page under the Bacillarieae. The Phaeophyceae and Rhodophyceae have relatively few, about a half page each, but these are of special interest because they are necessarily marine, and it is worthy of note that common genera with numerous species, such as *Ceramium*, have a large representation. The full page list on vegetable debris such as twigs, fruits, and soft tissued baits is of interest because of its variety and extent, and offers helpful hints to the collector, as do the categories of Pteridophyte spores, pollen of Gymnosperms, and pollen and mature plants of Angiosperms. Since the fungi that serve as hosts or substrata are practically all Phycomycetes, as are the fungi occurring on them, this list of one and one-half pages is at first glance confusing, but readily interpreted by the punctuation. The array of animals is interesting in that it comprises representatives from the Protozoa, Rotifers, Nematodes, Trematodes, Crustacea, Arachnids, Insects, and Ascidians.

The bibliography, occupying 44 pages, is one of the most complete, extensive, and valuable that has ever been assembled in this field, comprising approximately 600 references, ranging in alphabetical scope of authors from Agardh to Zukal, in time from 1824 to 1941, and in sources from the well-known monographs and papers through obscure, little-known literature in less familiar languages hidden in esoteric publications.

The index of 19 pages, although not very extensive in the less needed references to subjects, is very complete and useful in its inclusion of orders, families, tribes, genera, species, and other taxonomic entities, with synonyms in italics and technical descriptions in bold face.

The illustrations, after a frontispiece of four half-tone portraits of Dangeard, Zopf, Petersen, and Cornu, comprise 69 line drawings scattered through the text in appropriate places. Most of these text figures are original, either drawn by the author himself or prepared by Higgins and by Gracey for him; several are redrawn with appropriate acknowledgment, from work already published. They are a helpful supplement to the text, illustrating the significant characters of most of the genera and species, or effectively presenting life cycles, or comparisons of structural or developmental features within orders or other taxonomic groups.

This reviewer feels confident that any criticisms of this book will result more from differences of opinion on the part of the reader than from just reproofs of any errors or inadequacies. It is to be noted that in these groups there has been an almost complete lack of herbarium material that could be depended upon for taxonomic comparisons, hence the taxonomic approach has been chiefly through living material, and it is the thoroughness of the writer's painstaking study of such material during the last 15 years, both in this country and in Europe, that gives this volume its authoritative soundness. The taxonomic treatment is conservative, yet it does differ in some respects from that which has been used previously or is preferred by others. Some, for example, because of the parallelism in development and thallus structure, will question the writer's delimitation within the Chytridiales of the two parallel series, the Operculatae and the Inoperculatae, but as this characteristic is morphologically so clear cut, it serves as a valuable distinction here, as it has in the case of the Discomycetous Ascomycetes. Others, emphasizing the growth of organisms in pure culture as essential, will deplore the fact that practically all the critieria of distinction used in this book are based on the material living under approximately natural conditions, yet as collection under natural conditions always comes first and pure culture follows later, and as some groups have never yet been grown in artificial culture and probably will not be for some time, Sparrow's approach seems the natural and more widely serviceable one. The book is notably free from typographical or other errors, the only one striking the eye of this reviewer during careful reading being the astonishing instance of color-blindness in listing *Codium* among the Red Algae.

The book is a notable achievement. The University of Michigan Press should be complimented both on the excellent job they have done on the book itself and on their prodigality in making available in these times 785 pages of illustrated, technical, scientific material for $5.00. The author is to be complimented on by far the most authoritative, scholarly, and complete treatment of the aquatic fungi that has ever appeared. It is a monograph in the highest sense of the word, one that would have won the approbation of the great from deBary to Thaxter.

THE CARNIVOROUS PLANTS.

By Francis Ernest Lloyd. Chronica Botanica Company, Waltham, Mass.; G. E. Stechert and Co., New York. $6.00. $10\frac{1}{4} \times 6\frac{3}{8}$; xv + 270 + 38 plates; 1942.

So axiomatic and generally accepted is the fundamental concept that all animals are directly or indirectly dependent upon plants for food, that the very reversal of this lends a peculiar fascination to carnivory in plants. Not only laymen and amateurs, but also outstanding scientists such as Darwin, Goebel, and many others have felt this fascination and much scattered work has been done in the field. It is, therefore, the more commendable and welcome that finally Lloyd has completed this comprehensive, authoritative, and detailed study of the carnivorous plants. Any such study which traces a function or an activity through the diverse plants possessing it is bound to have a significant influence on science, and this authoritative volume without doubt will prove to be an epoch-making one.

Comprising in large part the author's own original work, yet with a masterly synthesis of all the pertinent work previously done by others, the book has a thoroughness and completeness that stamp it as outstanding. All possible aspects of the plants concerned—their taxonomy, anatomy, physiology, ecology, and relationship—are considered in detail, with authoritative knowledge derived from the writer's 13 years of enthusiastic devotion to this field, devotion that involved careful absorption of an extensive literature in several languages, and first hand study of living material on this continent, in Europe, and in more remote localities during two journeys—one to Africa, another to Africa and Australia—supplemented by extensive correspondence, by securing the cooperation of collectors and naturalists in favorable localities, and by periods of study at various botanic gardens and laboratories. In his ingenious and decisive experimental work the writer, in addition to the more classic methods previously employed, made effective use of motion pictures and time-lapse sequences—methods peculiarly suited to the problems involved.

The introduction furnishes the general background essential to the detailed chapters which follow. First it lists and tabulates, with their geographic distribution, the carnivorous plants, which comprise about 450 species, of which *Utricularia* alone includes more than half (275); *Nepenthes*, 65; and *Drosera*, 90; represented in 15 genera belonging to 6 families, 5 of which are in the Choripetalae while the largest one, the Lentibulariaceae, is in the Sympetalae. The wide distribution is notable, most of the genera having a wide range, large genera such as *Utricularia* and *Drosera* being ubiquitous, a few being more limited, such as *Cephalotus*, extreme southwest Australia; *Byblis*, from northwest to southwest Australia; and *Dionaea*, in North and South Carolina of the United States. The fundamental character of the traps is next considered, and they are arranged in order of complexity from the pitfalls or passive traps of the pitcher plants through the passive lobster pot trap of *Genlisea* up through the bird lime or fly-paper traps, passive in *Drosophyllum* and active in *Drosera*, to the active steel-bear-trap-like snap-traps of *Dionaea* and *Aldrovanda* to finally the complicated mousetraps of *Utricularia* and its relatives, *Biovularia* and *Polypompholyx*. This separation into categories on the basis of function or activity, interestingly enough, does not agree with the botanical classification, the Lentibulariaceae having the passive lobster pot trap of *Genlisea*, the active fly-paper trap of *Pinguicula*, as well as the complicated mousetrap of *Utricularia*. It brings out also the interesting fact that the greatest specialization has been reached by *Dionaea* and *Aldrovanda* of the Droseraceae with their active mechanisms analagous to a steel bear trap and by *Utricularia* in the Lentibulariaceae with its supermousetrap with its hair trigger operated door and inrushing suction. Secondary to the form and action of the traps are other characters contributive to their efficiency, such as methods of attracting prey by lures—odors in some, the secretion of nectar by glands either on the traps or leading to them in others, the exhibition of attractive colors and bright fenestrations in others, the gleaming of brilliant reflections from drops of mucilage in still others. Provisions for digesting the captured prey by means of secreted enzymes and acids are present in all but a few, and the conclusion seems obvious that, from the standpoint of nutritional physiology, the advantage of this remarkable specialization to the plant is the acquisition of nutrient substances containing protein, possibly vitamins, and perhaps salts of potassium, phosphorus, etc.

Then follows an interesting discussion of the question whether carnivory distinguishes these plants as something unique in the plant kingdom or whether there are significant similarities and counterparts among non-carnivorous plants. The writer notes the rather widespread occurrence of pitchers without carnivory either for attracting insects to accomplish pollination as in *Aristolochia*, or for holding nectar as in *Aquilegia*, or for harboring adventitious roots and sheltering ants as in *Dischidia*, or as reservoirs for reserve stuffs as in *Lathraea*, or for water reserves as in certain leafy liverworts. He then contrasts with true carnivory the situation in plants which have adhesive glands superficially resembling those of *Drosera*—plants such as the South African *Roridula* which offers so complete an analog that it was generally considered carnivorous until Lloyd himself demonstrated that it was not; or plants which have some spring mechanism, like the paleae of the grass *Molinia* that catches insects fortuitously with no advantage to itself. His justifiable conclusion is that there is nothing unique about any one feature of the carnivorous plants, rather "it is the constellation of their characters which stands out." Finally he discusses the constellation of characters which mark *Utricularia* as the most complicated, extra-

ordinary and interesting of all, with brief remarks on the possible evolutionary interpretation of carnivory.

The body of the book consists of 14 chapters considering the genera from *Heliamphora* through *Utricularia* in order of the increasing complexity of their trap mechanisms, each chapter taking up the taxonomy, history, structure, development, relationship, and characteristics of the plants considered, with of course special emphasis on the structure, physiology, and activity of the mechanisms by which they function as carnivorous plants. In these chapters the previous work of others is synthesized and presented, together with the original observations of the author.

Indicative of the thoroughness and completeness of the volume is the inclusion of chapter 11 on the carnivorous fungi, which, since their traps are either passive adhesive discs, or nooses both passive and active, fall in complexity between the passive lobster pot trap of *Genlisea* and the passive fly-paper traps of *Byblis* and *Drosophyllum*, yet are so remarkable in their beautiful adaptation for the capture and utilization of protozoa, nematodes, rotifers, etc., that they constitute a special field in themselves. This field, although known since the time of the pioneer work of Zopf in 1888, had been explored only fragmentarily by mycologists until the recent intensive work of Drechsler. For assembling and summarizing here this work on carnivorous fungi the author merits the admiration and gratitude of all with special citation for his intrepid and excellent review of the work of Drechsler, whose method of writing is so involved and complicated that only one like Lloyd, with preliminary experience in solving the involved and complicated mechanism of *Utricularia*, would attempt to clarify and present the material for the ordinary botanical reader.

Especially noteworthy is chapter 13 on *Utricularia*, *Biovularia*, and *Polypompholyx*, and the final chapter on the marvelously intricate trap itself. These alone would mark the volume as an outstanding contribution to biology. The final chapter does, indeed, support the author's contention that the trap of *Utricularia* is the most complicated of all carnivorous mechanisms. In matter of fact, it is so complicated one regrets that Lloyd did not schematize, diagram, and briefly schedule the complicated, beautifully timed sequence of events, for even after carefully rereading these 33 pages, the reader becomes so overwhelmed with details that it seems safe to wager that of all who review this book few if any, and certainly not this reviewer, would be able to give a completely satisfactory explanation of just how the trap really works!

Lightened by the touch, which those of us who have been fortunate enough to hear Lloyd lecture on this subject realize is characteristic of him, is the appendix with its model and description of two mousetraps, the earlier one, save for the typical Lloydian touch of the *Au Fromage* sign post, embodying the erroneously simple concepts of Cohn and Darwin, the second embodying the more recent interpretation which began with the experiments of the Swiss entomologist, Brocher, in 1911 and gradually progressed through added bits of evidence until Lloyd's own investigations finally yielded the complete explanation. Labelling this happy nightmare "with apologies to Heath Robinson" is another delightful Lloydian touch, lost perhaps on the American reader unless he realizes that in the field of goofy gadgets Heath Robinson is the British equivalent of our own Rube Goldberg.

The references are assembled after each chapter rather than in one list of *Literature Cited*. This, of course, leads to some repetition, Charles Darwin's *Insectivorous Plants*, for example, occurring in practically every bibliography, but it makes each chapter complete in itself, and in its entirety the book is very fully documented, all pertinent references being included.

The illustrations are effective supplements to the text. The frontispiece, a line cut of Nepenthes from Rumphius' *Herbarium Amboinense*, is of historic interest as the earliest known illustration of a carnivorous plant, while a charming sketch of a pitcher plant ends the book and graces the table of contents, and another of the sundew precedes the plates. Eleven line cuts serve as text figures, helpfully illustrating the text, from the first figure on the structure of the traps in *Heliamphora*, through those of structural details of other genera, to successive diagrams of the sucking in of prey by *Utricularia* and the two final mousetraps of the appendix, the Darwin Model T and the Lloyd De Luxe Model V-8. The 38 plates are in part clear-cut line drawings of structural details and in part half-tone reproductions from photographs or from the motion pictures themselves and from diagrammatic animation sequences. The line cuts are exceedingly clear and helpful, the photographs excellent, although some unfortunately have been considerably reduced and crowded together for economy so that their details are discerned with difficulty.

At the end of the book a two-page index of plant and animal names and an author index of two and one-half pages ably supplement each other in enabling the reader to locate readily the wealth of material and the numerous workers included in the book, while at the very beginning of the book a brief but informative biographical sketch introduces the writer.

The volume conforms to the high standards of the Chronica Botanica Series, of which it is the ninth. The paper is of high quality, as is the typography, and there is a notable freedom from typographical or other errors, so that, as befits its noteworthy content, the volume is a beautiful job of craftsmanship.

THE PLANT COMMUNITIES OF THE WELAKA AREA *with Special Reference to Correlations between Soils and*

Vegetational Succession. University of Florida Publication: Biological Science Series, Volume IV, No. 1. By Albert Middleton Laessle. University of Florida. Tallahassee. $1.50. 10 x 7; 115 + 14 plates; 1942 (paper).

This is a detailed and thorough ecological study of the University of Florida Conservation Reserve, a 2180 acre tract leased to the University by the Federal Government in 1939, and situated south of the village of Welaka in Putnam County. This tract, part of the Pamlico Terrace, lies along the Saint John's River in the low, relatively flat, coastal lowlands ranging from the flatwoods with elevations about 12 to 25 feet above sea level down to the bays with their marsh to submersed aquatic communities along the river. The study is based on over two years of field work, beginning in September, 1939, and may be roughly divided into three phases—first, the assembling and accurate determination of a herbarium comprising the vascular plants of the Reserve, about 750 species, with their ecological and seasonal variations; second, a careful soil survey with borings, studies of the macro and micro elements, and the preparation of a detailed soil map; and third, a study of the nature of the local plant communities and associations and their successional relationships, correlating these as far as possible with the character of the soil.

After a brief introduction outlining the scope and objectives of the work, the basic background is laid down in four chapters: a brief summary of the history of the Welaka area from the early visits of Bartram to the present; a brief discussion of the geology and of the Pleistocene subsidence and emergence responsible for the Sunderland and Pamlico Terraces and the present topography of the region; a short summary of the phytogeography and the floral differences in this region from that of the west side of the ridge; and finally a more detailed chapter on the climate, discussing the precipitation, with pertinent data on rainfall, temperature, with tabulations of the growing period and of the killing frosts, and also subsidiary ecological factors such as wind, lightning and fires, humidity, light, and drainage.

The main body of the work begins with a detailed, intensive study of the soils of the tract, presenting analyses of their macro and micro elements, discussing the results of the author's survey, with descriptions of the eight main types of soils found in the area, and in a detailed soil map graphically presenting the extent and location of these types. The next chapter considers in detail the vegetation of the region and the vegetational associations ("association" as used here indicating a fundamental unit of vegetation in the sense of the Brussels Congress) with diagrams and analyses of square meter quadrats in areas typical of the recognized communities. Also, the vegetational changes from one association to another are illustrated by bisects, some drawn to scale to show both the changes in species from one community to another and also the approximate height and layer relationships of the vegetation; others showing changes in the soil profile from one association to another, with lists of the plants characteristic at various points. A thorough study of the ecological distribution of plants in the Reserve is presented in the next chapter which, after brief explanation of the method of recording and evaluating the degree of dominance or non-dominance, devotes 28 pages to careful tabulation of the distribution and relative frequency of 750 species of vascular plants in 24 natural, semi-natural, or distinctly modified habitats. Finally, the chapter on succession gives strong evidence for interpreting the observed sequences of plant succession by correlating vegetational changes with soil development according to the concepts of Braun-Blanquet, discusses the influence of fire-climax vegetation on the hard pan or ground water podzols, and presents evidence for the author's conclusions as to the influence of soil, vegetation, and moisture on the invasion of one type of vegetation by another.

After a brief summary 39 pertinent references are given, followed by an index in which the plant associations and the soil types are in bold face, the technical taxonomic names in italics, and the remaining items in ordinary type.

The illustrative material effectively supports the text. The three tables of the killing frosts and growing season, the macro elements of the soils, and of the trees per acre in a typical pine stand, although compiled from other sources, are pertinent and helpful. Two charts, one of the average monthly precipitation at the nearest weather station, Crescent City twelve miles to the east, the other of the mean daily evaporation rates (from Rogers' study of the Florida Crane-flies), give fundamental and pertinent information. There are three maps, one on the general topography of Florida (from Cooke); the other two—the detailed soil map and the map of vegetation types—are by the author and of the highest excellence of draughtsmanship.

The 25 figures helpfully illustrate the text. Nineteen of these are diagrams of quadrat plots; while three are of soil bisects, one diagrammatic, the other two, figures 15 and 16, detailed and effective three fold bisects of a pond border with little versus much fluctuation; and three are vegetational transects, one from swamp of pine, another of a soil profile with accompanying vegetation, and another of stages of plant succession. The 14 plates comprising two figures each in fine screen half-tone are all from the author's photographs, and uniformly good, with the possible exception of one or two (cf. Pl. 7) that are lacking in contrast; they show the types of vegetation very adequately and effectively.

A few typographical errors, chiefly for some reason i's or lack of i's (e.g. Sporoboli*s*, visable, Salvi*n*a, di*c*iduous, etc.) and a few errors such as "the present elevation of the Reserve flatwoods are" seem to indi-

cate a lack of proofreading. If the aeroplane photographs used by the author were indeed so valuable in his mapping of the soils in the plant communities, it seems unfortunate that some of these were not included, unless perhaps war conditions preclude their use. The writer's statement that "The aeroplane photographs were so good that one could check his position in the field on them *to the width of a line*" is slightly confusing, leaving the reader wondering just how wide is a line; while to the northern ecologist inured to more rigorous winters the fact that there was no first killing frost in 1920, 1922, and 1923 leaves him somewhat confused until he realizes that the last killing frost was probably at the same time the first.

This able contribution fully maintains the high standards set by previous publications in this series, and both the author and the University are to be congratulated for what they have done toward advancing the scientific knowledge of their state.

COMMON EDIBLE MUSHROOMS.

By Clyde M. Christensen. University of Minnosota Press, Minneapolis. $2.50. 8⅛ x 5⅛; x + 124; 1943.

Wild mushrooms can be found in almost any locality during much of the year and yet very few people utilize them for food and those who do eat them often depend upon a few so-called tests to determine which forms are edible. None of these "tests" applies to all cases and all of them tend to exclude many forms which are perfectly edible. The only safe way to utilize these wild fungi is to know which species are edible and then learn to identify these forms with certainty.

This little book is intended to provide the information necessary for this procedure for those who are completely unacquainted with the subject. It is written in non-technical language and contains photographs of practically all of the forms discussed. The numerous pictures and the few easily recognized characteristics discussed for each form make identification a relatively simple process even for the beginner. The author also calls particular attention to those forms which may be confused with poisonous species. Forty-seven of the more common and easily recognized edible forms are discussed as well as a number of common poisonous varieties. The forms are divided into groups according to their spore color, but beyond this there has been little effort to arrange them in the form of a key, a fact which is probably not a serious handicap in a book dealing with only a few species. There are also short sections on finding and gathering mushrooms and on mushroom cookery.

Although the author's statement that it is best "to learn a few species well and avoid all others" undoubtedly represents sound advice, many readers of this book will soon find their interest extending beyond the limited number of forms discussed here. Some may also be bothered by the author's attempts at humor or human interest angles, but on the whole the book should prove of interest and value to many people who are not now acquainted with edible wild mushrooms.

FUNDAMENTAL PRINCIPLES OF BACTERIOLOGY. *Second Edition.*

By A. J. Salle. McGraw-Hill Book Company, New York and London. $4.00; 9 x 6; xii + 643; 1943.

The first edition of this excellent text appeared in 1939. The present, second, edition has been thoroughly revised, to embody all the advances in bacteriology which have taken place since the first edition was issued, and has been completely rewritten. As in the first edition considerable emphasis is placed on a sound knowledge of organic and inorganic chemistry. The most fundamental change, and one which many teachers of the subject will welcome, due to the fact that those with long teaching experience usually prefer their own laboratory guides, is the separation of the laboratory procedures from the text material.

The chapters which show significant reorganization are as follows: The morphology of bacteria; The microscope; The effect of environment upon bacteria; The nutrition of bacteria; The enzymes of bacteria; The respiration of bacteria; The fermentation of carbohydrates and related compounds; Associations of bacteria; Differentiation and classification of bacteria; Bacteriology of air; Bacteriology of soil; Bacterial and virus diseases of plants; and Specific infections.

A list of references is given for each chapter, and the volume is abundantly illustrated and well indexed. The final chapter (Chapter XXVII) gives a brief history of bacteriology.

LABORATORY MANUAL ON FUNDAMENTAL PRINCIPLES OF BACTERIOLOGY. *Second Edition.*

By A. J. Salle. McGraw-Hill Book Company, New York and London. $1.50. 9 x 6; ix + 184; 1943.

This *Manual*, originally part of *Fundamental Principles of Bacteriology*, has been thoroughly revised and rewritten. Emphasis, as previously, is on fundamental principles and facts. The course is arranged to cover a one-semester course of six laboratory hours per week, with enough material presented so that the instructor can make a choice, if he so desires. The ground covered meets the requirements of beginning students in the bacteriology major, and students in the various divisions of agriculture as well as forestry, home economics, pharmacy, dentistry, sanitary engineering, chemistry, physical education, hygiene, and public health.

PREMIÈRES OBSERVATIONS BOTANIQUES SUR LA NOUVELLE ROUTE DE L'ABITIBI (MONT-LAURIER-SENNETERRE). *Contributions de l'Institut Botanique de l'Université de Montréal, Number 42.*

By Frère Marie-Victorin and Frère Rolland-Germain. Institut Botanique de l'Université de Montréal, Montreal. 50 cents. 9 x 6; 50; 1942 (paper).

DRACAENA CUBENSIS. *Contributions de l'Institut Botanique de l'Université de Montréal, Number 43.*

By Frère Marie-Victorin. Institut Botanique de l'Université de Montréal, Montreal. 25 cents. 9 x 6; 18; 1942 (paper).

MORPHOLOGY

THE HANDLING OF CHROMOSOMES.

By C. D. Darlington and L. F. La Cour. The Macmillan Company, New York. $2.50. 7⅞ x 4⅞; 165 + 16 plates; 1942.

No cellular structure has been studied so intensively during the last decades as the chromosomes. Though they are known better than any other cell constituent, none presents a greater variety of problems. Today they are the subject of a science in itself. This advance during recent years has been due to a large extent to the development of diversified methods in handling chromosomes. A compilation of these techniques in one volume is, therefore, of great importance for the student as well as the research worker.

The present volume is an attempt to fill the need of a comprehensive treatise on the subject. It is unfortunate that it does not fully reach its goal. For beginners in the art of treating chromosomes the instructions are mostly too short and often obscure. The advanced cytologist is disappointed by the incompleteness, not only in the methods described but also in the material suggested as suitable. The list of organisms for living study, for instance, is pitifully short. The chapter on X-rays is hardly understandable for the novice and offers little to the advanced student. The centrifuge is dealt with in one sentence: "Experiments have been made for various purposes by....." Similarly we are told: "most combinations of chromosomes and breeding work are too obvious or too elaborate to be given here." Photography has become an important tool in the study of chromosomes. Yet, besides some short instructions on how to build a camera for the microscope, there is little in the short chapter which would help to overcome specific difficulties in photomicrography of the nucleus. The last chapter tells how to describe the results of microscopic studies. With much of it every cytologist will agree. Not a few, however, will disagree with the authors' evaluation of drawings. The careful and detailed illustrations of the early cytologists "derived little from art and contributed nothing to science." According to Darlington "what is needed, however, is a drawing which, i) can be reproduced cheaply, ii) will show the reader, true or false, exactly what the draughtsman thought he saw. For these purposes pen-and-ink drawing alone is suitable." Everyone who has looked for some specific information in cytological papers knows how much can be found in the painstakingly realistic drawings of early cytologists. The diagrammatic black and white illustrations of Darlington's followers, on the other hand, show indeed nothing more than what the investigator believed important as evidence for his hypothesis. Any other structure or phase is lost until someone else with different interests happens to work on the same type of cell again. How much information—though at the moment seemingly unessential—must get lost in this way?

Despite these shortcomings and despite certain inaccuracies and statements like: "the nucleus is the chromosomes. In the nucleus the apparatus of cell-government is at rest, in the chromosomes it is in movement", the book contains much worthy information. Especially useful are the tables of chromosomes in natural groups, the chromosome calendar telling when and where to find material for study, and the compositions of fixatives and schedules of treatment. A series of magnificent photomicrographs, well reproduced, demonstrate both possibilities and limitations of photography in chromosome work. Even though the book does not meet the demands of the student nor of the advanced investigator it gives a much needed summary of the many techniques applied today to the study of chromosomes.

THE EMBRYOLOGICAL TREATISES OF HIERONYMUS FABRICIUS OF AQUAPENDENTE. *The Formation of the Egg and of the Chick* [De Formatione Ovi et Pulli]. *The Formed Fetus* [De Formato Foetu]. *A Facsimile Edition, with an Introduction, a Translation, and a Commentary.*

By Howard B. Adelmann. Cornell University Press, Ithaca, New York. $12.00. 10½ x 6¾; xxiv + 883; 1942.

With notable scholarship and historical zest Adelmann has brought to life again the crochety, erratic, and brilliant Paduan anatomist, Fabricius of Aquapendente. During his professorship from 1565 to 1613 this great man not only made important contributions to embryology by his own investigations, but he introduced the subject to a long series of able students. The most important of these, William Harvey, frankly followed the work of his teacher in his own studies of embryology. It is not too much to say that by his teaching and especially by his two books Fabricius brought about the emergence of embryology as a special branch of science.

In the present volume we are given facsimile repro-

ductions of *The Formed Fetus* (1604) and *On the Formation of the Egg and of the Chick* (published posthumously in 1621). These reprints are accompanied by complete English translations, in which Adelmann has succeeded in unraveling the difficult Latin of Fabricius and in making his ideas clear by copious and instructive notes. Readers who are deeply interested in the history of embryology will be grateful for the ample cross-references to the predecessors of Fabricius, especially Galen, and to the text of Harvey's *De generatione animalium*. The book is prefaced by a life of Fabricius which tells us not only the details of his somewhat stormy intellectual and professional career, but gives a vivid picture of medical education in the Padua of his day.

In a long introductory essay the history of embryology before Fabricius is described in detail, and his two treatises are analyzed with regard to their content of fact and philosophy. Fabricius, like Aristotle and Galen, was chiefly anxious to explain the embryo by working out the "final cause" of each organ and part; that is to say, the end or purpose it has to serve. Structure and function are studied in the light of the supposed useful purpose. Such an approach, characteristic of the scholastic period, naturally produces a great deal of conjecture as to the final cause, and leads to much and often misguided teleological inquiry. Not the least of Adelmann's services to his readers is his clear explanation of his author's viewpoint. We are allowed to see and understand how the mind of the great embryologist adjusted his observations to the traditions and doctrines which inevitably guided his thinking. His clear and often astonishingly accurate descriptions of the egg and the chick, the mammalian placenta and membranes, the placental and fetal circulation, are well brought out.

The book is handsomely made up, and the printing and binding are worthy of its important subject and of the great learning, intelligence, and labor which Adelmann has spent in its preparation. Such a work will do much to promote an understanding of the past and respect for our great predecessors. It should be called to the attention of every graduate student and medical student interested in embryology. For professional embryologists its reading is a necessity.

HUMAN EMBRYOLOGY.

By Joseph Krafka. Paul B. Hoeber, Inc. New York and London. $4.75. 9¼ x 6⅛; xi + 394; 1942.

The present volume is one of a new series specially prepared to meet the present day needs of undergraduate medical students facing a much crowded curriculum. These "student textbooks", according to the editor's preface, are designed to present "what the student has time to read at a price he can afford to pay" —something perhaps between a compendium and an outline (!).

In his attempt to present "a short but complete account of the development of man" the author in his preface tries to justify (1) omitting all reference to comparative embryology; (2) eliminating virtually all reference to causal factors in development; and (3) the elimination of laboratory exercises. The omission of (3) is of little consequence, since few institutions follow exactly any prescribed laboratory procedure, but to leave out entirely "to save space" any mention of the present day concepts of experimental embryology, evolution, and genetics, seems poor economy, to say the least. As a whole the text is more superficial than concise. In the first 66 of the 361 pages, eight chapters dealing with the following topics (including literature references) are disposed of post-haste: General embryological concepts; Historical development of human embryology; The male and female reproductive tracts; Hormonal control of the genital system; Fertilization and cleavage; The youngest known human implanted ovum: Hertig-Rock No. 7699. The other 300 pages are concerned principally with organogenesis and are rather wearisome. According to the author he has "retained the basic data contributed by that illustrious group of investigators who wrote the individual chapters of Keibel and Mall." Various parts of the text, particularly the descrjptions of the early stages, have been brought up to date by including some of the newer data from the publications of the Carnegie Institution of Washington Department of Embryology.

The text is illustrated with some 200 figures (pen and ink drawings) redrawn in the majority of cases from previous publications. A reference list chosen to include human material is found at the close of each chapter. The volume is indexed.

ANATOMY AND PHYSIOLOGY LABORATORY MANUAL AND STUDY GUIDE. *Second Edition, Revised.*

By Barry Griffith King and Helen Maria Roser. W. B. Saunders Company, Philadelphia. $2.75. 11¼ x 8½; xi + 253; 1943 (paper).

This laboratory manual and study guide has been written for use with any of the standard texts on anatomy and physiology. The exercises are designed to help the student learn by active participation in the laboratory and by summarizing the knowledge gained from the lectures, reading, demonstrations, laboratory experience, and other teaching methods. An attempt has been made to direct attention to normal structure and function by occasionally making the student his own experimental subject and by constantly encouraging him to interpret his own responses in everyday activity in terms of anatomy and physiology. The authors offer a relatively large choice of practical exercises, many of which have been performed in nursing classes. The selection of material, the order of presentation, the time devoted to any particular system

of the body, and the indications of the relative importance of the details studied are left entirely to the judgement and experience of the instructor. This is a feature of the manual which should be much appreciated by all experienced teachers, since many similar laboratory manuals are entirely too inelastic to suit the desires and requirements of the individual instructor.

The subject-matter is here presented in five independent units—the body as an integrated whole, the erect and moving body, metabolism of the body, the reproductive system, and the nervous system. No specific reference is made to a text unless a pertinent discussion of the material is difficult to find. The book is furnished with an excellent assortment of illustrations, charts and tables. Ample space is provided for the answering of questions. Additional questions for review are provided at the end of each unit. An appendix has been included to help the instructor in assembling and purchasing physical equipment for the laboratory and to acquaint the student with techniques that are useful in laboratory experimentation—including anesthesia, electrical stimulation, and kymograph recording.

The manual will be found useful, not only for nursing schools, but for general college anatomy and physiology courses as well.

PALMAR AND PLANTAR DERMATOGLYPHICS IN PRIMATES. *The American Anatomical Memoirs, Number 20.*

By Charles Midlo and Harold Cummins. The Wistar Institute of Anatomy and Biology, Philadelphia. $3.00. 10 x 6⅞; 198; 1942.

The significance of dermatoglyphics in the taxonomy of primates has long been recognized, but the literature has consistently shown a scarcity of materials observed. The number of palms and soles observed for the present study, including many original living and preserved members as well as many illustrations from the literature, exceeds by far that of any previous study. The result is a comprehensive work on the comparative analysis of the origin, evolution, variations and affinities of the dermatoglyphics of the primates.

The data are ample for a quantitative study not only of the form and intensity of the configurational palmar and plantar patterns, but of the variations and asymmetries as well. Several of the authors' conclusions are worthy of astute consideration. One such conclusion is that the appearance of specific dermatoglyphic patterns has been the result rather than a cause of the evolutionary development among the primates. Another is that on the basis of the present study of intensities and asymmetries among the various dermatoglyphic patterns of the primates, in which man has been shown to be more primitive than orang, ". . . it is concluded that man stemmed from an ancestral stock more primitive than any recent ape, having dermatoglyphic traits more closely allied to those of monkeys."

The work is well illustrated and documented and presents a wealth of tabular material. A table of contents is included, but no index is provided.

THE ANATOMY OF THE NERVOUS SYSTEM *from the Standpoint of Development and Function. Seventh Edition, Revised.*

By Stephen Walter Ranson. W. B. Saunders Company, Philadelphia. $6.50. 9¾ x 6½; xii + 520; 1943.

The first edition of this book appeared in 1920. From its beginning it has been noted for its excellence of presentation and for the skillful manner in which it correlates form and function. The present edition, which was completed just prior to the untimely death of the author, maintains this high standard.

The pace of neurological research has been so swift that, although the previous edition was published as recently as 1939, it has been found necessary to make rather extensive additions and alterations. That this has been accomplished without undue lengthening of the text is a tribute to the author. The many new illustrations, however, are a welcome addition.

Presentation of the subject matter has been slightly changed. The chapters dealing with cerebellum, diencephalon, cerebral cortex, and autonomic system have been revised and rewritten. That on the diencephalon has undergone special revision so as to include the results of recent investigations, and is notably improved. A new chapter, dealing with the meninges and blood vessels of the brain, has been added. The illustrations of the sheep brain, formerly scattered throughout the text, have been collected and placed at the end of the atlas.

This book always has exerted a strong and beneficial influence on the teaching of neuroanatomy in this country. There is little doubt that, in its latest edition, it remains one of the best textbooks on the subject in any language.

HANDBOOK OF MICROSCOPIC CHARACTERISTICS OF TISSUES AND ORGANS. *Second Edition.*

By Karl A. Stiles. The Blakiston Company, Philadelphia. $1.50. 9 x 6; xi + 204; 1943 (paper).

The success and popularity which this excellent little handbook has earned in the past two years well merits the present revision. The new materials and the few changes incorporated in the present edition have resulted in an improved supplementary text and workbook for the student of histology.

The first few chapters of the textual material deal

with the various types of tissue cells. The balance of the volume is devoted to the histology of the various organ systems of the body. The materials are presented in outline summary form, supplemented frequently with tabular charts. Blank pages are provided for lecture notes, drawings, references, or any other comments pertinent to the subject under discussion.

The volume is attractively bound and carries a glossary and an index. The present edition of this fine work will undoubtedly meet further success in its field, since it will certainly enhance the study of histology in the present accelerated program of study in the fields of biology and medicine.

LABORATORY DIRECTIONS FOR HISTOLOGICAL TECHNIQUE.

By Alfred Brauer. Burgess Publishing Company, Minneapolis. $1.25. 11 x 8½; 43; $1.25 (paper).

This manual contains surprisingly complete and up-to-date directions for a one-semester college course in histology. Since the outline is prepared essentially for students of zoology, physiology, bacteriology, premedical students, and those preparing for careers in medical technology, methods in entomological and parasitological techniques have been held to a minimum and histological technique has been emphasized. Subject-matter presented is the following: material supplies and equipment, general outline of procedure for processing tissues, fixing, washing, dehydration, clearing, infiltrating, imbedding, sectioning, affixing sections on slides, cleaning slides, staining and mounting, some biological stains, clearing agents, whole mounts, smear techniques, special techniques (including bone, connective tissue, nervous tissue, embryos, hepatic glycogen, and mitochondrial techniques), and the microtome knife. There is a very helpful chart provided which includes and gives directions for each of the steps involved from the beginning fixing process—using seven different fixing agents—to the final act of covering the material on the microscope slide. The manual contains a brief list of available reference books on the subject and concludes with an index.

AN OUTLINE MANUAL FOR THE STUDY OF HISTOLOGY.

By Arthur J. Gatz. Burgess Publishing Company, Minneapolis. $1.75. 10¾ x 8½; 80; 1941 (paper).

This laboratory manual provides outline descriptions of the tissue systems, sufficient material being given to enable the student to identify the components by himself in the majority of cases. Every other page has been left blank for student notes or drawings.

PHYSIOLOGY AND PATHOLOGY

CONSTITUTION AND DISEASE: *Applied Constitutional Pathology.*

By Julius Bauer. Grune and Stratton, New York. $3.50. 8½ x 5¾; ix + 208; 1942.

The author of this most welcome and stimulating book is a former professor of medicine in Vienna and an outstanding authority on constitutional problems. In his preface he describes constitution as follows:

> It is taken for granted . . . that the potential energy of the germ plasm accounts for the development of a full-fledged human being out of a fertilized ovum of microscopic proportion in the short period of nine months. It is not adequately realized, however, that this potential energy is at work throughout a whole lifetime; that the physiologic evolution and involution, the structure and function of the organs, their mutual relation, and the response to various stimuli depend on this potential energy; that deficiencies and abnormalities of this potential energy may be cooperative etiologic factors or the sole cause of diseases; that they account for the vast majority of congenital malformations in man. And this potential energy is just what we might call individual constitution.

This concept excludes strictly all environmentally induced characteristics of an individual as part of his constitution. At a later place the author comments as follows regarding the relation between constitution and race:

> What was originally a constitutional trait and became a familial one by hereditary transmission, may eventually become a racial characteristic by natural or sexual selection. As a matter of fact, it is the accumulation of such a constitutional trait in the population that justifies the term racial characteristic.

A large part of this volume deals systematically with the constitutional inferiority of organs and tissues. Another part discusses the integrative systems of individual constitution on the basis of what the author has termed the "principle of treble safeguard". The latter recognizes and stresses the fact that most functions of an organism are dependent upon, and regulated by, the proper interaction of a particular organ with the endocrine system as well as the nervous system. Individual differences in the symptomatology of various diseases can often be explained on the basis of abnormalities in one or another of these three regulating and cooperating factors. There follows a chapter devoted to the classification of normal and abnormal constitution, starting with the blunt assertion that "there are as many different constitutions as individuals." The last major chapter is chiefly of clinical interest inasmuch as it is concerned with diseases which have mainly a constitutional etiology, such as diabetes, obesity, various blood diseases, peptic ulcer and cancer. Much of this discussion reaches into the domain of medical genetics.

This scholarly and original work closes with the following warning:

It must be kept in mind that although endowed with the most perfect and valuable endocrine preparations, we are not able to adjust their administration to the requirement of the body as precisely as the production and liberation of hormones is adjusted to the requirement in the normal body. It is beyond our power to imitate exactly the nervous factors that regulate the discontinuous production and output of hormones under normal conditions. We should be modest and more reluctant to interfere with the precise mechanism of the living machine without necessity.

There is an extensive bibliography, but no index.

VIRUS DISEASES. *The 1942 Messenger Lectures on the Evolution of Civilization.*

By Members of The Rockefeller Institute for Medical Research: Thomas M. Rivers, Wendell M. Stanley, Louis O. Kunkel, Richard E. Shope, Frank L. Horsfall, and Peyton Rous. Cornell University Press, Ithaca. $2.00. 9¼ x 6; viii + 170; 1943.

Virus diseases are not new, but the recognition of them as a group of maladies different in certain respects from those caused by protozoa, fungi, spirochetes, and bacteria has taken place in the last fifty years. Thus, when used in connection with certain maladies, the term *virus* no longer has a general or indefinite meaning, but has acquired a definite significance similar to that carried by the word *bacterium*, *bacillus*, or *spirochete*. It has been necessary to develop special methods of investigating the phenomena of infection and resistance in the different fields of biology, and consequently one should not be surprised to find that many new techniques have been used in the study of viruses and the diseases caused by them. Even though the general principles of other infections apply to virus maladies, the causative agents of the latter have been found sufficiently different from those of the former to upset some old and accepted ideas.

The six sections of the present volume deal with the following subjects: virus diseases with particular reference to vaccinia; chemical structure and the mutation of viruses; new hosts as a key to progress in plant virus disease research; swine influenza; human influenza; and viruses and tumors. It is emphasized that many new virus diseases have been discovered in recent years and that, although virus workers are not always in agreement and the same virus worker not infrequently changes his ideas, many facts about these peculiar agents have been established and are sufficiently important and interesting to warrant their being brought together under one cover. In the present series of Messenger Lectures, virus workers of recognized authority have attempted to do this for the fields with which they are familiar. Bibliographies are given at the end of each contributor's article. There is no index. The volume makes a significant contribution to the field of virus literature and should prove helpful to physicians, public health workers, immunologists, research investigators, and all other students of these interesting ultramicroscopic forms of life.

CREATINE AND CREATININE METABOLISM.

By Howard H. Beard. Chemical Publishing Company, Brooklyn. $4.00. 8½ x 5½; x + 376; 1943.

Although creatine was recognized many years ago as a significant factor in muscle physiology, the subject of creatine and creatinine metabolism has remained a much disputed and imperfectly understood field. The literature on this subject has become very extensive, but much of the work is conflicting and inconclusive for one reason or another. It is against this background that Beard has attempted to summarize our present knowledge in this field.

The book covers practically every subject to which creatine and creatinine metabolism can be related. Various chapters deal with methods of determination, distribution in the animal body, various steps in the formation of creatine and creatinine, relation to water metabolism, excretion, various phases of muscle metabolism, tumor growth and regression, and many other subjects. In many of these sections the author has extended his discussions beyond the immediate field of creatine and creatinine metabolism into such topics as carbohydrate and amino acid metabolism, muscular contraction, phosphate bond energies, etc. The subject of creatine and creatinine metabolism cannot be treated in a vacuum and such an expansion is to be expected in a book of this type. However, one does not and should not expect to find these fields as completely covered as the main topic.

It would be a mistake to assume that recent work has cleared up all or even most of the controversial questions in this field, and there will undoubtedly be many who will disagree with the point of view presented by the author on various questions. However, this should not lessen the value of the book for such workers. There is an extensive bibliography provided, many of the techniques employed are discussed in some detail, and the whole is provided with both subject and author indexes. It therefore represents an ideal starting point for anyone interested in investigating a particular point more thoroughly.

Although the book will be most valuable to those who are actively interested in its field, the various clearly written sections should aid teachers and biologists in general in clearing up many of the misconceptions about this subject which exist at the present time in many minds.

FOOD POISONING.

By G. M. Dack. The University of Chicago Press, Chicago. $2.00. 9 x 6; xi + 138; 1943.

Knowledge of food poisoning has increased so rapidly during recent years that books on the subject have often become dated or have been too limited in scope to serve the many groups now concerned with food poisoning. Food superstitions, the bogey of "ptomaine poisoning," and other popular misconceptions persist among the general public. Moreover, the current revolution in American eating habits, drastic upsets in supply and distribution of food and food products, and changes in methods of processing and packaging foods have heightened the need for an authoritative statement of our newest and best knowledge of food poisoning, compiled in readily available form.

This book, written by an acknowledged authority in the field, is a heartening attempt to fill this need. It is primarily a critical discussion of the various agents which may cause food poisoning. Similarities and distinctions are drawn so that the volume will be of practical help to individuals engaged in studying the numerous gastrointestinal upsets which may or may not be due to food poisoning. As a general term, food poisoning is here limited to outbreaks of an explosive nature which are generally characterized by gastrointestinal upsets. Among the important exceptions, however, is botulism, in which the gastrointestinal symptoms are usually a minor feature of the disease. The causative agents included in the volume are: chemicals, poisonous plants and animals, bacteria and their products, protozoa and helminths, and a miscellaneous group of illnesses the causes of which are unknown. Of these agents, the bacteria, which form toxins in food before ingestion, are discussed at greatest length. In addition to generous citations from the literature, which are presented in the form of footnotes, original experiments not previously reported in the literature are included. A complete index concludes the volume. Although not a textbook, the book should have particular value for all who are professionally concerned with food poisoning, for students of medicine, nursing, food bacteriology, and home economics, and for state and municipal public health workers. To all of these, as well as to the intelligent layman, this excellent volume is heartily recommended.

THE SCIENCE OF HEALTH.

By Florence L. Meredith. The Blakiston Company, Philadelphia. $2.50. 9 x 6; xi + 427; 1942.

This volume is the second edition of *Twelve Hours of Hygiene*, the title having been changed with the change in scope and organization of the material. The stated purpose of the author remains the same; it is for use in one-hour, one-semester college courses in hygiene. The teacher familiar with the first edition will note that the chapters on anatomy, physiology and the lesions of disease have been reduced; that the introduction has been extended to give a picture of the health situation in the country today; that more space has been given to the vital matters of nutrition and physical training and to several other current health problems of personal and national importance, including parenthood and the welfare of the next generation, and nervous and mental disorders; and that a new section has been included on mental hygiene.

The author has made a special effort to do the following: to give facts usable by the student in making his own decisions, to give opinions generally held by medical science, to weight the material properly, to arrange the material so that its order and sequence in itself will be educational in effect, and to use scientific terminology in so far as it will help to clarify the student's thinking. Subject matter presented includes: the body in health and disease; supply, use and renewal of energy; thermal regulation; cleanliness; bacterial, physical and chemical injury; major disorders of internal origin; brain and nerves; mental health; and the next generation. The appendix includes sections on: chemical composition of foods, vitamins, mortality statistics, health organizations, medical education, and medical specialists.

The excellent illustrations, including charts, graphs and other tabular material, are a distinct feature of the book. An extensive bibliography and a complete index conclude this well-written, well-balanced and attractively printed and bound volume. It is recommended to all students and teachers of college hygiene courses and to the general public as well.

THE METABOLIC COST OF MAINTAINING A STANDING POSITION *with Special Reference to Body Alignment.*

By Harriet Graham McCormick. King's Crown Press, New York. $1.25. 9 x 6; 75; 1942 (paper).

Does "good" posture take less energy to maintain than "poor" posture? Is there, or is there not, a relationship between the way an individual stands and the amount of energy he uses in maintaining that position? If there is such a relationship what is the alignment of the body which is associated with minimum energy expenditure and what with maximum? These are questions which are being asked by students of orthopedics, body mechanics, and physical education. A number of investigations have already been made on this matter of the metabolic cost of standing and of closely related problems, but there is still little unanimity of opinion among authorities in the field. It was the purpose of the present study to provide more experimental evidence in the hope of throwing more light on this matter. Specifically, Mrs. McCormick

has studied the following problems: (1) Is there any relationship between the alignment of the body in the standing position and the variation in metabolic increase in the standing rate over the basal rate, and if a relationship exists, how does body alignment vary with this increase in metabolic rate? and (2) Is there any relationship between the increase in metabolic rate and the scores in a given posture test?

Material discussed includes: the history and background of the problem, collecting the data, results of the metabolism determinations, measuring body alignment, the relationships with metabolic increase, and the implications of these findings. The book is illustrated with appropriate photographs, charts and tables. The appendix contains directions for marking the photographs for measuring. There is an extensive bibliography, but no index. The author's findings, here reported with clarity and precision, should interest and serve all who are concerned with the basic problem or with the related one of helping individuals to improve their body mechanics and posture.

HUMAN PHYSIOLOGY AND ITS APPLICATIONS.

By Harrison M. Tiets. Burgess Publishing Company, Minneapolis. $3.00. 11 x 8½; 324; 1942 (paper).

The aim of this book is to present physiological facts in a fairly simple manner by avoiding long technical discussions. For this reason the author has not included experimental evidence to support the various theories. There has also been omitted any reference to current articles and source material. The author feels that the average student has neither time nor inclination to use these references, and in this he is probably quite correct. The human body is considered as a complex machine and with this idea in mind the author has divided his discussions of each system into three parts: (1) a section devoted to anatomy, or the names and locations of parts; (2) normal physiology, or the natural functions of these parts; and (3) a chapter dealing with practical considerations, in which diseases, etc. of a system are discussed on the bases of a disfunction of some organ or organs. The excellent drawings, all of which are the original work of the author are exceedingly numerous, well planned, and well executed and add materially to the value of the book from the student's point of view.

The volume begins with an introductory chapter on cells, tissues, organs and systems and then proceeds to elaborate on the skeletal system and associated tissues; the muscular systems; foods, digestion and the structure of the digestive system; the structure and physiology of the blood and of the circulatory system; the lymphatics; the anatomy and physiology of the respiratory and reproductive systems; excretion; the nervous system; structure and physiology of the eye and ear; reactions and motor pathways; the cerebellum and the kinesthetic sense; autonomic nervous system; speech and language; the skin; metabolism; and the internal secretions. Many students, particularly those in the pre-medical curriculum, will find the chapters on the practical considerations especially interesting because in these discussions they can see the application of physiological facts to health and disease. A very complete index is appended to the volume.

FUNDAMENTALS OF IMMUNOLOGY.

By William C. Boyd. Interscience Publishers, Inc. $5.50. 9 x 6; xiv + 446; 1943.

This book, written as an introduction to immunology for medical students, chemists, and biologists, not only covers the field thoroughly for the beginner but also deals with advanced problems which will interest the professional immunologist. It is assumed by the author that the student will have had some acquaintance with chemistry and bacteriology when he comes, in his curriculum, to this subject.

For the beginner, Boyd stresses the basic principles of immunology—the fundamental mechanisms of immunological reactions and their theoretical foundations—on the ground that these once mastered, their application will not be found difficult. The chapter headings are as follows: Immunity and immunology; Antibodies and antibody specificity; Antigens; Cell antigens; Blood groups; Antibody-antigen reactions; Complement and complement fixation; Anaphylaxis and allergy; Allergy and immunity; bacteria; viruses, parasites; Practical use of artificial immunity; Laboratory and clinical technic. In the last-mentioned section (Chapter XI—the longest in the book) are given detailed descriptions of theoretical and practical serological procedures, with a sufficient number of experiments provided so that some selection can be made by the instructor for class work. The author has adopted the method of distinguishing that part of the text intended for advanced workers by the use of smaller type. This seems a most satisfactory procedure, especially for those students whose interests carry them beyond the introductory course.

Each chapter in the volume concludes with a list of references to recent and pertinent literature. Some of these lists are quite lengthy, in one case running to 187 titles. Tables and figures occur throughout the text and an excellent working index is provided. A text which undoubtedly will be well received by both teachers and students.

THE INFECTIOUS DISEASES OF DOMESTIC ANIMALS *with Special Reference to Etiology, Diagnosis, and Biologic Therapy.*

By William Arthur Hagen. Comstock Publishing

Company, Inc., Ithaca. $6.00. 9¼ x 6⅛; xxvii + 665; 1943.

This excellent text, based on the author's experience for many years as a teacher in the field will be widely accepted as a guide for courses in veterinary medicine. It departs from the usual method of presentation of the subject in that a knowledge of the general principles of bacteriology is taken for granted and so is omitted. This makes it possible to give space to fungi, protozoa, and viruses that are pathogenic for the domestic animals and to discuss more fully the nature of the diseases produced by the various agents and the biological products which are available for their diagnosis, prevention, and cure.

The volume is divided into six parts. Part I (8 chapters) deals with the mechanisms of infection and resistance; Part II (19 chapters) is concerned with the pathogenic bacteria; Part III (3 chapters), with bacteria-like pathogenic organisms of uncertain classification; Part IV (2 chapters), with the pathogenic fungi; Part V (7 chapters), with the pathogenic protozoa; and Part VI (5 chapters), with the viruses.

Each chapter concludes with a list of references for further reading, the 145 figures are well chosen and their reproduction is excellent. The index is adequate, although in a volume containing such a wealth of material the reviewer believes that a more detailed index would be an advantage.

A book that is destined to become one of the standard texts in its field. It will also be valuable as a reference to the veterinary practitioner, the research worker, the laboratory technician, and the intelligent person who is so situated that at times he is obliged to depend upon his own resources in the treatment of his animals.

THE SIGHT SAVER.

By C. J. Gerling. Harvest House, New York. $2.00. 8 x 5⅓; 202; 1943.

Realizing that the average person knows little about eyes, what may go wrong with them, common defects, diseases, disorders, accidents, etc. that may affect them, the author has prepared this practical volume of general information for the layman. He feels that good, serviceable eyesight is generally a matter of taking advantage of the many means available for the protection and correction of vision, but he makes it clear that his book is merely to acquaint one with what may be done for ailing eyes and in no sense is to be considered as information for self-treatment. "The very delicacy of the eyes that makes them need attention also demands that this attention be given only by the trained and experienced hands of a graduate physician or oculist."

One valuable feature of the book is the information which is given on widely advertized eye products such as patent medicines, lotions, washes, cosmetic aids to beauty, etc. which are either harmless mixtures or extremely harmful, often producing sight impairment, blindness or even death—in all cases ineffective for their advertized purpose. Information is also given on various widely exploited branches of eye quackery including the "sight without glasses" racket.

Instead of following the customary form of chapter divisions the various subjects are arranged in alphabetical sequence with cross references according to the general principles of the encyclopedia. Such an arrangement has made possible a vast amount of information within a small compass. Under the heading Books on the eyes, sight, etc. one finds a list of inexpensive pamphlets issued by the American Medical Association, free pamphlets issued by reliable organizations, and popular and technical books on vision which will be helpful to those wishing further reliable information.

CLINICAL DIAGNOSIS BY LABORATORY METHODS. *A Working Manual of Clinical Pathology. Tenth Edition, Thoroughly Revised.*

By James Campbell Todd and Arthur Hawley Sanford. W. B. Saunders Company, Philadelphia and London. $6.00. 9¼ x 6; x + 911; 1943.

Medical technicians, doctors, teachers, and students will welcome the tenth edition of this already well-known book. The rapid improvement of old techniques and the discovery of new ones have justified an extensive revision. Much new material and a considerable number of illustrations have been added. A few of the new additions and changes may be mentioned.

There is a new arrangement of the material on rickettsial diseases, the Quick prothrombin test is described, the fluorescent dye method of staining tubercle bacilli is included, tests for sulfonamides and sulfones in the blood and methods of identifying sulfonamides and sulfones in the blood and methods of identifying sulfonamide crystals in the urine have been added, diseases due to fungi are given brief treatment and Brewer's new methods for growing anaerobic organisms are described. The chapter on clinical chemistry has been augmented by addition of the Haskins and Osgood titration method for the determination of the alkaline reserve figure and the Ågren and Lagerlöf methods for the determination of trypsin and amylase. The Somogyi technique for the determination of serum amylase is likewise given.

It is not worth while enumerating all of the new additions, revisions, and deletions. However, only methods which have clearly become obsolete have been omitted. Where two or more techniques are still in general use, all are included, as for example, in the serodiagnostic tests for syphilis.

LE PROBLÈME DU CANCER.

By Charles Oberling. Les Éditions de l'Arbre, Montréal. $1.50. 7⅝ x 5¼; 298; 1942.

An exposition and critical review of experimental work on the etiology, rather than treatment, of cancer forms the major portion of this book. The material was originally presented in a series of lectures given in Paris and Téhéran to medical students and physicians. With the aim of making the material available to a larger group of readers, the lectures have been revised for publication, mainly by the omission of the more technical details and the inclusion of explanations of technical terms. Chemical, genetic, bacteriological, pathological and parasitological aspects of the problem are considered.

BIOCHEMISTRY

PROTEINS, AMINO ACIDS AND PEPTIDES AS IONS AND DIPOLAR IONS. *American Chemical Society Monograph Series.*

By Edwin J. Cohn and John T. Edsall, including chapters by John G. Kirkwood, Hans Mueller, J. L. Oncley and George Scatchard. Reinhold Publishing Corporation, New York. $13.50. 9 x 6; xviii + 686; 1943.

This volume is number 90 of the monograph series dealing with various chemical problems, sponsored by the American Chemical Society. The series has come to play an important rôle in current chemical thought and research by bringing together in single volumes and in a well-digested form the pertinent material on a given subject. The publication of these monographs has been carried out with two primary aims. In the first place, works such as this tend to stimulate and organize research in the field with which they deal by providing a well-organized and readily available summary of the work to date, thus indicating new directions in which research may be profitably followed. A second, and equally important, function served by such a work is in providing readily accessible information for those who are working outside of the specific field discussed by the monograph. The growing dependence of other fields upon various branches of chemistry and the extensive interdependence of the various chemical fields themselves makes this second service of extreme importance.

The present monograph does not attempt to cover all phases of the chemistry of amino acids, peptides, and proteins, but rather limits itself to a consideration of these molecules from the standpoint of their size and shape and the number and distribution of the electrical charges which they bear. As the authors point out in the preface, they are considering above all, "... the implications of their charged structure for their physical properties, and their physicochemical interaction with other molecules". The basis for this field of research was provided largely by the work of Debye and Hückel on the interionic forces in electrolyte solutions, and that of Bjerrum which showed that even at their isoelectric point aliphatic amino acids bear both positively and negatively charged groups, i.e. they are dipolar ions or *Zwitterionen*. Advances have been rapid in the two decades since this fundamental work, but as one would expect, the work on proteins themselves has advanced much less rapidly than that on the simpler amino acids and peptides.

Most of the work of preparing this volume was done by a small, closely-knit group of workers centered around the Harvard Medical School and the Massachusetts Institute of Technology. Their close association has probably contributed much to the unity with which the various phases of the subject have been presented, and the fact that this may have led to some narrowness of viewpoint is offset by the abundant references to the original work on the subjects considered. These should prove adequate for any who may disagree with interpretations arrived at in the text. An extensive subject index and a tabular index of data on many amino acids, peptides, and proteins also adds to its value as a reference work.

This is not a book which will appeal to those with only a passing interest or a scanty background in the subjects discussed, but it will undoubtedly be a valuable addition to the reference lists of many who are actively interested in these problems.

THE ANTIGONADOTROPIC FACTOR *with Consideration of the Antihormone Problem.*

By Bernhard Zondek and Felix Sulman. Williams & Wilkins Company, Baltimore. $3.00. 9 x 6; viii + 185; 1942.

The organ response to various pituitary preparations is not constant but falls off in the course of protracted treatment. Systematic research on this subject showed that experimental animals respond to continuous administration of gonadotropic substances with formation of substances capable of inactivating gonadotropic hormone both *in vivo* and *in vitro*. This class of substances was termed antihormones by Collip.

Zondek and Sulman, working in the newly founded Hormone Research Laboratory of the Hebrew University, Jerusalem, have made a number of valuable contributions to this field. They now present their original experimental material—much of it hitherto unpublished—with a general survey of the antihormone problem in the form of a monograph. In an introductory chapter the historical development of the problem is discussed and concise definitions of the terms used for the various hormones and antihormones are given. The units of dosage also are clearly defined in this chapter. The laboratory and clinical studies of

the authors lead them to the view that the production of an antigonadotropic factor through prolonged treatment with gonadotropin is an immune reaction. However, the antigonadotropic factor does not give the *in vitro* reactions which generally characterize an antibody. This concept differs from Collip's antihormone theory. Collip postulates a buffer-system of hormones and antihormones, which are normally in a state of equilibrium in the animal body. If an animal, which possesses a well-balanced hormone buffer-system is protractedly treated with large amounts of a certain hormone, the corresponding "antihormone" level rises. In this way equilibrium is re-established and the blood of the animal receiving treatment contains easily detectable amounts of "antihormone". In Zondek's and Sulman's monograph the arguments for and against Collip's interpretation of the antihormone phenomenon are excellently presented.

The chapter on the clinical significance of the antihormones should be read by every clinician who finds it necessary to undertake protracted therapy with gonadotropic hormones. Not only the endocrinologist, but every biologist interested in the mechanism of hormonal correlations in the animal body will find this book full of stimulating ideas. An excellent bibliography enables the reader to delve further into the scattered literature of this fascinating field.

NOXIOUS GASES *and the Principles of Respiration Influencing Their Action. Second and Revised Edition.* *By Yandell Henderson and Howard W. Haggard. Reinhold Publishing Corporation, New York.* $3.50. 9 x 6; 294; 1943.

Gases differ fundamentally from solids and liquids in their physical behavior. Accordingly, poisonous gases and vapors have characteristic effects upon men and animals exposed to them, distinct from noxious substances in solid and liquid form. This book deals primarily with the special features of toxic action dependent upon volatility. The classification and description of volatile poisons are necessarily different in some respects from those usually employed in toxicology as well as from those which chemistry would suggest. The mode of classification adopted here is practical rather than strictly logical. The literature primarily devoted to the particular topic of volatility as a factor in toxicology is small as yet, but is increasing, and it is only with the special features due to volatility and entrance through the lungs that the present authors are concerned. The references given here are therefore confined to two purposes: (1) particular points, usually on toxic concentrations, and (2) general references placed at the end of the chapters. Only those gases which occur in industry are dealt with; their use in war is not discussed. References to works dealing with chemical warfare are, however, given at the end of the chapter on irritant gases. Material presented includes: elements of respiration; the respiratory functions of the blood and their laws; practical applications of the laws of gases and vapors; principles determining absorption, distribution, and elimination of volatile substances; classification of noxious gases and vapors; irritant gases; asphyxiation and simple asphyxiants; volatile drugs and drug-like substances; methods of resuscitation and comparison of various treatments; and prevention of poisoning by noxious gases.

The aim of the authors is not so much to contribute to treatment or to aid in the winning of compensation as it is to make available the knowledge, the principles, and the techniques upon which measures of prevention and of safety in industry must be based. Bibliographies are appended to most of the individual chapters. A complete index is provided. The volume contains much material of practical use for chemists, engineers, physiological hygienists, and others engaged in industry. It deserves a wide reading by those whose work is in these fields.

LABORATORY DIRECTIONS IN BIOCHEMISTRY. *By Victor C. Meyers. C. V. Mosby Company, St. Louis.* $3.50. 10½ x 7½; 288; 1942 (paper).

This laboratory manual has been written primarily for medical and dental students who are attempting to cover as large a number of different topics in biochemistry as possible in a limited period of time. It brings together a large number of commonly utilized experiments and presents them in the briefest possible form.

Over half of the book is given over to the strictly clinical aspects of the subject, particularly as related to urine and blood analysis, and even the first 120 pages, which supposedly deal with biochemistry in a more general sense, definitely anticipate the clinical sections which follow. In the general section the primary emphasis is upon the detection of various substances, and quantitative tests are largely confined to the clinical section where their precision is usually considered in terms of clinical requirements rather than in terms of the characteristics of the reaction itself. This general clinical emphasis seems in many cases to prevent the adequate utilization of the experiments to demonstrate general biochemical principles, reaction mechanisms, etc.

On the whole, this manual represents a compilation of a large number of experiments in much the same form as they are found in the "home-made" laboratory manuals used in many places, and presented in much the same "cook-book" fashion. These are supplemented by a limited number of references, particularly in connection with quantitative methods. It will undoubtedly be useful to students interested in biochemistry as a routine clinical book, but to those who consider biochemistry as a field in itself which is capable

of throwing light on many of the fundamental problems of both physiology and organic chemistry it will appear to miss the point. Although the type of presentation which this manual represents is widely used, its adequacy in providing a foundation for further work in biochemistry, or indeed for a clear understanding of the basic principles involved in biochemical reactions, may be questioned.

ADVANCES IN ENZYMOLOGY *and Related Subjects. Volume II.*

Edited by F. F. Nord and C. H. Werkman. Interscience Publishers, Inc., New York. $5.50. 9 x 6; viii + 374; 1942.

This carefully-prepared, well-edited, and thoroughly documented book is an authoritative treatise on enzymology and related subjects which represents the considered research and conclusions of fifteen recognized and established American, British, Swiss, Danish, and Japanese investigators. It is the second volume in a series of at least four planned works. It represents the latest word concerning the multifarious investigations already completed, now underway, and contemplated in this rather new and absorbing field of scientific interest. Two of the articles in the book are in German; the remainder are in English. Subjects discussed include: bacterial viruses (bacteriophages), the kinetics of hydrolytic enzymes and their bearing on methods for measuring enzyme activity, a classification of proteolytic enzymes, the enzymatic properties of peptidases, diamin-oxydase, the chemistry of tea-fermentation, heterotrophic assimilation of carbon dioxide, enzymes associated with respiration and fermentation of *Aspergillus*, cellulose decomposition by micro-organisms, a unified hypothesis of the reciprocal integration of carbohydrate and fat catabolism, the chemistry and physiology of Vitamin K, and the adrenal cortical hormones. The book is attractively printed and very substantially bound. The illustrative material is well chosen and very helpful. Each section is replete with its own extensive bibliography—a total of over 1000 references being given. The volume concludes with both an author and a subject index and a cumulative index of Volumes I and II. A work which will be of general interest and considerable value to chemists, physiologists, research workers, and others who are concerned with this rapidly developing field of science.

TEXTBOOK OF BIOCHEMISTRY. *Third Edition, Revised. By Benjamin Harrow. W. B. Saunders Company, Philadelphia.* $4.00. 9 x 6; ix + 537; 1943.

Through two previous editions this compact textbook of biochemistry has come to be one of the most widely used and recommended books in its field. It is smaller than most texts in biochemistry, but the material is well chosen and more than adequate for the needs of any elementary biochemistry course. Actually, this book has come to be relied upon by a great many biologists as a dependable source of biochemical information outside of their immediate field of interest, and its value as a reference book is enhanced by the short, but well chosen, bibliographies which accompany each chapter. Review articles and references to other books are emphasized, and most of the entries are accompanied by a note on their particular value.

The third edition has been expanded by almost one hundred pages. A new chapter on immunochemistry and chemotherapy has been added, and many sections have been revised and expanded, including those on various phases of intermediary metabolism, hormones, viruses, sulfhydryl groups and their significance, detoxication, etc. There are also timely discussions of wartime problems dealing with nutrition, blood plasma, etc.

This book is comprehensive in scope and remarkably up-to-date for a textbook of its type. The previous editions of the book were excellent, but the expansion of the present volume should add considerably to its usefulness. It will undoubtedly continue to be widely used for both class work and general reference.

REPORTS OF THE BIOCHEMICAL RESEARCH FOUNDATION OF THE FRANKLIN INSTITUTE. *Vol. VI, 1940–1941. Franklin Institute, Newark, Delaware.* 9¾ x 7; Collection of reprints.

The papers presented in this volume (23 in number) have been reprinted from various sources and cover a wide range of subjects in the field of biochemistry and physicochemistry in relation to disease, experimental physiology, etc. Ellice McDonald, Director, contributes an interesting progress report of the work of the Institute—in its fifth year in 1940, at the time that the report was written.

In the latter half of the volume are reprinted notes from the Biochemical Research Foundation which have appeared in the Journal of the Institute. These are concerned largely with methodology and techniques and abstracts of experimental work and seminar reports.

SEX

SEX AND RACE. *A History of White, Negro, and Indian Miscegenation in the Two Americas. Volume II. The New World.*

By J. A. Rogers. J. A. Rogers Historical Researches, New York. $3.00. 9 x 6; 409; 1942.

This unusual compilation of old and new data, facts and more or less plausible assertions, amazing and *risque* "case histories," sound and biased theories, and numerous, but poorly reproduced, pictures, all appertaining to racial hybridization in the New World, is of interest to the historian and sociologist rather than to the biologist. The first 150 pages deal with Latin America, the remainder with Anglo-Saxon America. Race-mixture in South America is more intensive than anywhere else in the World. Many men of mixed ancestry have played prominent rôles in Latin American history and culture. There exists little racial discrimination to this day, indeed, even beauty contests are not restricted to whites in Brazil. It is a pity that far too little scientific study has been made so far of this huge "melting pot" which represents an anthropological experiment on a continental scale and with unpredictable outcome.

That miscegenation in North America has been and still is more wide-spread than is commonly believed, seems apparent from this volume. Of the many and often disconnected chapters in the second part of the book the following samples may here be named: "White people sold as Negro slaves," Rivalry between white wives and Negro concubines," Rich Negroes with white wives during slavery," "Noted white Americans with Negro ancestry," "Hannah Elias, the black Cleopatra," and among the appendices "Body odors and their sexual effect."

The author's diagnoses regarding racial purity are not very scientific. Thus he states: "It is not improbable that Columbus was of mixed blood. His complexion was olive; his cheek-bones were high, and his lips, as seen in the Yanez portrait, were of the full Negroid kind." The book contains no conclusions and no index. It is evident that the author regards the prevalent treatment of the Negro in North America as unjustifiable and that he seems to favor removal of all social and legal barriers to race-mixture. He does not appear to be aware of the fact that racial hybridization is primarily a biological problem.

BIOMETRY

STATISTICAL ANALYSIS IN BIOLOGY.
By K. Mather with a Foreword by R. A. Fisher. Methuen and Company, London. 16s. 8½ x 5½; 247; 1943.

This book would be more appropriately entitled "Significance Tests for Biological Data" for it is limited almost exclusively to that subject. The use of the broader title may be due to the fact that the author's own uses of analysis have been so much confined to sampling tests that he thinks of these as making up the whole field. In fact he states:

"Practically the whole field of present-day statistical analysis depends upon the comparison of variances and co-variances" (p. 35) and again, "The use of the c, t, χ^2 and z distributions forms the last stage of the statistical analysis of a set of data. The preceding operations are concerned with reducing the data to a state in which the question at issue can be answered by means of a comparison between observed and expected deviations in the way made possible by the test distributions" (p. 48).

When we consider the large body of work in physical biology, physiology, epidemiology, etc., where rational equations have been developed from a study of the observations, the last stage seems a long way beyond significance tests, useful as they are along the way. In the last chapter the author mentions that these tests are actually only a part of the story, for he says, "Broadly speaking, statistical operations fall into two categories, viz. tests of significance and estimation of parameters" (p. 203). But even though he devotes a part of this chapter as well as some sections of the preceding ones to the subject of estimation, the reader is left with the impression that when we have determined the probability that the parameters differ significantly, our problem is done.

The significance tests are presented largely through applied problems which are very well chosen. The interpretations of the tests are not always justified, however. For example, in discussing the tests mentioned above, the author states, "Thus rigorous inferences may be reached from observational data alone, without involving any assumptions about the parent populations" (p. 49). What he should say is that no assumptions are made about the *parameters* of the parent populations, but since the distributions are assumed to be normal and it can not be known whether this assumption is correct, the inferences are not rigorous in the sense implied.

There is some tendency to allow incorrect statements for the sake of simplification. For example, it is stated that the value of the center of the parent normal curve, μ, and of σ may be estimated in various ways. Two ways are suggested for estimating σ, by averaging the deviations from the mean, ignoring sign, or by getting the root mean square. It is then stated, "Now these various ways of estimating μ and σ would all lead to the same value, viz. the true value of each parameter, if an infinitely large number of observations were available" (p. 27). This certainly creates the erroneous impression that in an infinite series of observations from a normal distribution, the mean deviation and the standard deviation are the same.

The book must therefore be read critically and the beginning student should be warned that he may have to correct some of the over-simplified interpretations as he increases his understanding of the subject, and will certainly have to enlarge his ideas as to what statistical analysis means.

THE FUNDAMENTAL PRINCIPLES OF MATHEMATICAL STATISTICS *with Special Reference to the Requirements of Actuaries and Vital Statisticians and an Outline of a Course in Graduation.*

By Hugh H. Wolfenden. The Macmillan Company of Canada, Toronto. $5.00. 8½ x 5½; xv + 379; 1942.

This text-book is presented "with special reference to the requirements of actuaries and vital statisticians." The particular requirements which the author had in mind were those pertinent to acquiring a broad view of the subject matter, and this has governed the rather unusual arrangement of the book. The first 150 pages constitute the body of the text and, in eleven chapters, present not only the topics included in the usual elementary text but also such subjects as systems of generalized frequency curves, various curves of relationship between two variables, methods of curve fitting including least squares, outlines of recent researches and of a course in graduation. Mathematical derivations and applications to numerical material are omitted from this part of the discussion. The second part of the book is divided into three sections: A, History (25 pages); B, Mathematics and interpretations (85 pages); and C, Applications (87 pages). There are also two bibliographies, the first containing publications of historical significance (190 titles), and the second, those of present value (177 titles). The book is adequately indexed.

This form of presentation is very convenient in using the book as a reference text or handbook. The beginning student will probably find the initial sections somewhat too condensed and be forced to refer back and forth from the text to the sections on application and interpretation. Fortunately these are well cross-indexed. That the author finds some difficulty in maintaining the sectional separation is indicated by the inclusion within the text itself of discussions and interpretations of some topics. For example, the presentation of Student's z and t distributions is followed by four pages (pp. 46 to 49) of discussion of the assumptions, meaning and applicability of the tests based on these distributions. This type of discussion is very useful as an integral part of the exposition of method and might well have been used more liberally.

The methods for the most part are presented very clearly. In Chapter III on the point binomial and normal curve, there is some confusion created by the use of n both for the size of sample and the number of samples (pages 12 and 17).

The book unquestionably furnishes a useful addition to the list of statistical texts, partly because it considers statistical analysis much more comprehensively than do most texts and partly because it has a fresh viewpoint.

ON THE PRINCIPLES OF STATISTICAL INFERENCE. *Four Lectures Delivered at the University of Notre Dame February, 1941. Notre Dame Mathematical Lectures Number 1.*

By Abraham Wald. Notre Dame, Indiana. $1.00. 9 x 6; 47; 1942 (paper).

In this publication, four lectures which were delivered at the University of Notre Dame in February, 1941, are presented in book form. The material is organized here in six sections, as follows: I. Introduction, in which the problem of statistical inference is formulated and the underlying concepts discussed; II. The Neyman-Pearson theory of testing a statistical hypothesis; III. R. A. Fisher's theory of estimation; IV. The theory of confidence intervals; V. Asymptotically most powerful tests and asymptotically shortest confidence intervals; VI. Outline of a general theory of statistical inference.

The final section contains a consideration of certain restrictions present in the theories previously discussed and outlines a more general theory free of these restrictions. The author discusses three steps essential in building up such a theory:

1. Formulation of the general problem of statistical inference.
2. Definition of the "best" procedure for making statistical decisions, i.e. definition of the "best" statistical decision function.
3. Solution of the mathematical problem of calculating the "best" statistical decision function.

He points out that the second step is always to a certain extent arbitrary, and that differences between tests for the same problem lie in this question of definition. The book is necessarily condensed but the basic concepts are clearly presented. A brief bibliography referring to more extensive discussions of the matter is appended.

THE DESIGN OF EXPERIMENTS. *Third Edition.*

By R. A. Fisher. Oliver and Boyd, Ltd., Edinburgh. 12s. 6d. 8¾ x 5½; 236; 1942.

The third edition of this book differs only slightly from the first, published in 1935, and the second published a year later. The new material in this edition consists of two new sections in the chapter on "confounding"—a technique designed to study and control the heterogeneity in the material.

The ideas presented are an extension of those on the techniques of experimentation discussed in Chapter VIII of the author's *Statistical Methods for Research Workers*. The first two chapters which are an introduction and a discussion of the principles of experimentation orient the reader with regard to Fisher's philosophy of scientific experimentation and are worth

careful reading in order to understand the emphasis the author places on certain portions of statistical methodology. His point of view is summed up in the statement, "Every experiment may be said to exist *only* [italics ours] in order to give the facts a chance to disprove the null hypothesis" (p. 16). That is, he states that the discovery of whether or not a significant difference exists is the sole purpose of the experiment, rather than an estimation of the order of the difference, the size of the parameters, or the development of new hypotheses.

In the course of the discussion the author does indicate that at least a part of the interest of the experimenter is in the magnitude of the parameters found. Nevertheless the main consideration in designing experiments is oriented to those techniques of significance tests included under the general head of analysis of variance.

Particular attention is given to problems arising in agricultural experimentation but the discussion is by no means confined to that field.

TABLES OF PROBABILITY FUNCTIONS. *Volume II.*

$\frac{1}{\sqrt{2\pi}} e^{-x^2/2}$ and $\frac{1}{\sqrt{2\pi}} \int_x^\infty e^{-x^2/2}\, dx$. *Federal Works Agency; Works Projects Administration for the City of New York as a Report of Official Project No. 165-2-97-22 Mathematical Tables Project.*

Conducted under the Sponsorship of the National Bureau of Standards. Arnold N. Lowan, Technical Director. National Bureau of Standards, Washington. $2.00. 10½ x 7¾; xxi + 344; 1942.

This volume is one in a series of mathematical tables prepared by the *Project for the Computation of Mathematical Tables.*

The two tables included give areas and ordinates in a normal probability curve of unit standard deviation, corresponding to a given deviation from the center. In Table I the areas are given within the range $\pm x$ and in Table II, outside the range $\pm x$. The functions are tabulated to 15 decimal places in Table I, the argument being given at intervals of .0001 from 0 to 1, and at intervals of .001 from 1 to 7.8. Table II gives the function to 7 significant figures in the range of x from 6 to 10 at intervals of .01.

These tables are a valuable extension of previous tables not only because they save the trouble of interpolation and extrapolation frequently required in using more condensed tables, but because they furnish a source from which various types of condensed tables may be taken.

The work has been done with the careful supervision for avoidance of error that has distinguished the other tables prepared by this group.

THE BULLETIN OF MATHEMATICAL BIOPHYSICS. *Volume 5, Number 3, September, 1943.*

Edited by N. Rashevsky. University of Chicago Press, Chicago.

This number contains the following papers: The kinetics of enzyme inactivation, by Alston S. Householder and George Gomori; Note on anodal excitation, by Alston S. Householder; On the theory of amoeboid movements, by N. Rashevsky; Studies in the mathematical biophysics of discrimination and conditioning: III, by H. D. Landahl; Book review: D'Arcy Wentworth Thompson, On Growth and Form, by Gerhardt von Bonin.

PSYCHOLOGY AND BEHAVIOR

BIRD DISPLAY. *An Introduction to the Study of Bird Psychology.*

By Edward A. Armstrong. Cambridge, at the University Press. $5.50. 8½ x 5½; xvi + 381; 1942.

The study and interpretation of bird behavior on a scientific basis has only recently been achieved. The advancement has been rapid and the nature of the world in which the bird lives is now being revealed by the careful observations of the modern ornithologist. How rapid these strides have been is indicated by the wealth of data presented in this volume. The writer does not limit display to the conspicuous ceremonial activities of some birds, but includes any activity that initiates a response. Thereby the writer justifies the subtitle of this volume.

The author begins by describing the ceremonies of the gannet, a species that is large, showy, and easy to study. After analyzing the displays exhibited by this bird, the details of the various ceremonies are elaborated upon with examples from other species. Each type of display is thoroughly described and its significance discussed. An attempt is also made to trace the evolution of certain behavior characteristics. Thus, nest building is conceived as developing from aimless actions arising under emotional stress. These activities, if favorable and valuable in assisting the survival of the species, become formalized and fixed and gradually change into a definite activity pattern that culminates in the construction of a nest. The function of courtship feeding is to stimulate and maintain the emotional relationship between the pair of birds. In this case the female behaves like a young bird by quivering her wings and by assuming the attitude and uttering the

notes of a young bird. The writer interprets this action as a recapitulation on the part of the female—during immaturity the bird was craving food, in maturity the craving she feels is for sex satisfaction, although she approaches it through the channels formed by an earlier desire.

Birds are tied down to fixed artificial displays which help maintain physiological harmony. If the recipient is out of rhythm, a set of abnormal, ineffective, and unrelated reactions are released, but if the birds are attuned, the recipient of the formalized display responds in the proper manner. Likewise many ceremonies have as a sole purpose the attainment of physiological rhythm. These gestures are then a substitute for speech with each species having its own language, but only the right key will open the lock that releases the functional activities of the bird.

Some of the topics include disablement reactions, greeting ceremonies, social ceremonies and social hierarchy, arena displays, territory, song-flight and others. Each topic in turn is developed and expanded with comparisons drawn between bird behavior and that of other animals, including man. In fact some of the latter comparisons are rather ingenious, although the critical reviewer may not be impressed by the resemblance.

In such a study, derived mostly from field observations, the accuracy of the observer is of prime importance. For this reason each statement is carefully annotated. The writer has also strived to avoid any anthropomorphic interpretations, long associated with the anecdotal school of bird watchers. As a consequence the data offered herein form a valuable and useful storeroom of information as well as a significant contribution to the analysis of bird behavior. There are some interpretations to which all may not agree and some that may be based on insufficient evidence, but the writer is not dogmatic.

The scientific names of the birds mentioned in the text are given in an appendix. The bibliography consists of thirty pages and is in itself a valuable contribution. This book should not be overlooked by any bird student or by anyone interested in animal behavior or related fields.

AUTONOMIC REGULATIONS: *Their Significance for Physiology, Psychology and Neuropsychiatry.*

By Ernst Gellhorn. Interscience Publishers, Inc., New York. $5.50. 9 x 6; xii + 373; 1943.

This is a very welcome book on the interrelations of the various elements of the autonomic system and their relations with cortical cerebral activities. The book has developed out of Gellhorn's lectures at the University of Illinois, College of Medicine, and the numerous illustrations in the text for the most part have come from his laboratories.

The book is divided into four parts: First, a general introduction devoted to anatomical and physiological foundations of the autonomic system. The second part deals with adjustment reactions involving primarily the respiratory and circulatory systems; for example, adjustment reaction to carbon dioxide, to anoxia, to asphyxia, to hemorrhage, to hypoglycemia, and the autonomic regulation of cerebral circulation. Part three is concerned with the autonomic-endocrine integration, the nervous regulation of the hormones of the hypophysis, the sympathetico-adrenal and vago-insulin systems. Part four is concerned with autonomic-somatic integration, the rôle of the sympathetic and parasympathetic systems in anoxia, hypoglycemia, and hemorrhage; fundamental differences in the reaction of the autonomic and somatic nervous systems and their significance for adjustment reactions; the relation of the autonomic and somatic nervous systems; and the autonomic basis of emotion. Part five deals with the results and applications—physiological results, and clinical results and applications. The physiological result finally is concerned with an effort at development of an organismal physiology, and in the final part, the clinical results, the material points up to an effort at a physiological interpretation of schizophrenia.

The material is lucidly presented, and even a person who is relatively unskilled in the vast amount of work that has been done on the autonomic system will have no great difficulty in following the presentation, particularly since each chapter ends with a very useful and comprehensive summary of the details previously presented.

There is a most impressive bibliography, and author and subject index.

It is no fault of the author that the chapter on the physiological basis for schizophrenia is perhaps the least telling. His efforts to bring together the physiological consequences of the various types of shock treatment is most useful, and may furnish a basis for further efforts to control this most difficult of all disease processes. The researcher in psychosomatic effects should find in this volume numerous starting points for further investigations.

CUCKOO PROBLEMS.

By E. C. Stuart Baker. H. F. and G. Witherby, Ltd., London. 25s. 8¾ x 5½; xvi + 207; 1942.

It is a well-known ornithological fact that the majority of parasitic cuckoos lay eggs that resemble to a greater or less degree the egg of the selected foster parent. The writer's first problem is to bring forth some evidence to show that this adaptation is necessary for the survival of the cuckoo. Desertions were found more frequently in nests wherein the parasite's egg did not match the fosterer's very closely and some observations

indicate that the unlike egg was actually ejected. Several experiments were performed to show that birds can discriminate unlike eggs, hence it is believed that this egg mimicry is essential.

The second problem attempts an answer to the question whether any evolution has taken place in adaptation of cuckoo eggs to those of the fosterer. Resemblance of eggs is not so close in Western Europe as in Central and Eastern Europe or in Asia. The writer therefore presumes that the cuckoo existed in Asia and Eastern Europe longer than in the West, and therefore had a longer time to perfect its adaptation. Time is thus the dominating factor in the evolution of adaptation in cuckoos' eggs. This reasoning is used to explain why the British Common Cuckoo lays eggs at variance with its victim's.

The writer discusses how the eggs are laid in the nest, citing two definite methods, but still expressing the belief that the bird in some cases must actually pick up the egg in its bill to deposit it in an inaccessible nest. No direct confirmation of this act is proffered, all the evidence being merely circumstantial. Recognition of cuckoos' eggs, territories, the manner in which young cuckoos eject the fosterer's eggs and other problems of vital interest in connection with the cuckoo are other topics taken up.

It is to be regretted that the writer uses the word 'proven' so often, for although much evidence is presented to favor his premises, yet much of it was gathered from second hand sources and is therefore open to suspicion. The eggs were apparently gathered in a random fashion and consequently the reliability of the sampling is to be questioned. However, the writer's 70 years of experience with cuckoos and their eggs certainly earns him the title of an authority on the subject and much valuable and incomparable data lies packed within these covers. Colored plates show clearly the resemblances or dissimilarities between the parasite's eggs and those of the victim. In addition, there is a lengthy annotated list of the eggs in the writer's collection which total well over 5000 in number.

MENTAL HEALTH IN COLLEGE.

By Clements C. Fry with the Collaboration of Edna G. Rostow. The Commonwealth Fund, New York. $2.00. 9 x 5⅞; xix + 369; 1942.

Fry, one of the original staff of the Division of College Psychiatry and Mental Health at Yale University and its director for some years, has, with the collaboration of Edna G. Rostow, Research Assistant in Psychiatry and Mental Hygiene, brought together a résumé of the case material of the past 17 years since the service's founding.

In this volume there is a great deal of important material concerned with the problems in adaptation of college students to the college life and to the facts of their own personality development, specifically the matter of family relationships, and of sexual growth, behavior, and attitudes. These topics are handled in a very broad, inclusive, and sensible manner, and will appeal to all of those people who look to the colleges as a source of something besides technical information. The last two of the four parts of the book deal with reactions to the undergraduate environment and special problems, particularly among the graduate and professional schools.

It is to be noted that serious disorders falling into the genuine psychotic groups are relatively rare. The problems are essentially those of personality adjustment, essentially within the limits of the normal.

To single out one item of particular interest in this very welcome book, one may mention a very regrettable item, namely, that those students of the medical school who came for psychiatric help had a much less open mind and inquiring attitude about psychotherapy than the students from any other one group. One would like to know whether this state of affairs would be duplicated at other schools. If so, we are faced with the conclusion that the students in that branch of science which inevitably will be most concerned with personality problems are showing a most regrettable resistance to the understanding of certain facts of life, deficiency in which will prove a handicap to their efforts at treatment of patients. This is no new problem, but some of us had thought that a considerable stride had been made toward eradicating it.

Parents with students in college might well be glad that the kind of development represented at Yale and encompassed in this book has spread rather generally. Fry and Rostow have done a very good job in presenting the factual material of their years of work.

PSYCHOLOGY IN NURSING PRACTICE.

By Philip Lawrence Harriman, Lela L. Greenwood, and Charles E. Skinner. The Macmillan Company, New York. $3.25. 8¼ x 5⅛; ix + 483; 1942.

This text-book of psychology for student nurses discusses the fundamental psychological notions of behavior, emotions and motives; consciousness, concepts, meanings, thinking, the concept of self, volition, etc. Anatomicophysiological phenomena in so far as they influence psychological processes, or are supposed to do so, are rather extensively treated. This seems to be rather useful as the thought of most physicians evolves along the same lines. From the practical purpose of the book it is understandable that special accent is laid on educational and pathological psychology. By appropriate remarks in the general chapters, as well as in special chapters (Personality and its development, Mental hygiene, Psychology of the patient, Psychology and the art of nursing), the special psychological problems of the nurse are developed.

One may agree or disagree with every single affirmation in such a vast survey; it must be recognized that the book in general is a very fair and able cross section of present day psychology, written with a lot of common sense and avoiding the somewhat sweetish style which has sometimes spoiled other nursing textbooks. Except in the excellent chapter of R. M. Lindner on "Mental deficiency and mental disorder" (praiseworthy also for his cautious attitude towards shock treatment), there is a certain tendency to minimize the contribution of psychoanalysis which seems unjust to the present reviewer, although he is himself by no means an adept of this school. After all Freud has influenced present day psychological thought and terminology more than anyone else. Even the frustration-aggression concept, so liberally used throughout the book, would probably not exist without Freud.

In solving rather well the difficult problem of summarizing the psychology of our society, the book is unintentionally an interesting and not always pleasant to look at mirror of this special, somewhat hectic mentality. It is one of the many excellent textbooks the possession of which other professions may envy nurses. It is a very good idea to prepare nurses mentally for a profession, psychologically so difficult, in a sensible and scientific way. Indeed it is a pity that the same is not done for young doctors who, to a large extent, face the same problems and are by no means better equipped by nature to master this task.

INFANT AND CHILD IN THE CULTURE OF TODAY: *The Guidance of Development in Home and Nursery School. By Arnold Gesell and Frances L. Ilg in collaboration with Janet Learned and Louise B. Ames. Harper and Brothers, New York and London.* $4.00. 9⅞ x 7½; [xii] + [399]; 1943.

Gesell and Ilg, the pediatrician in the Clinic of Child Development at Yale University, have presented a very interesting textbook of infant and child development in the democratic culture of today. The text is important for its two theses: First, that the child is a growing concern and the rôle of the adult is one of collaboration and guidance rather than training and imposition of outside disciplines; and second, the culture in which the child grows is important for his eventual outcome.

As a practical matter the book presents a "behavior day" and chart, done in detail as all such things are done in the Yale Clinic, with representative behavior profiles from the beginning of things up to 5 years and after, with very good summaries of what one might expect from youngsters at various age levels.

There is a good chapter concerned with the nursery school as a guiding center, with answers to the perennial question, "Should my child go to nursery school?" Observation of the "behavior day" leads to increased emphasis on the child's spontaneity for cues for collaborative guidance. This is particularly startling in the matter of child feeding, where it is recommended that the child be fed whenever it is hungry. Grandmother would approve of this.

The last part of the book has to do with the philosophy of growth, an attitude toward the whole problem of child development which might very well be made a *sine qua non* of our professional dealings with children. A very useful appendix gives actual samples of the behavior day chart, organization of the Yale Nursery, toys, play materials, and equipment for various ages, books for preschool children, musical records for infants and young children, and finally selected readings in the field of child guidance.

The format is very attractive, and the material is lucidly presented with a minimum of highly technical material. It can be generally recommended as an excellent text.

WOLF-CHILDREN AND FERAL MAN. *IV. Contributions of the University of Denver. By the Reverend J. A. L. Singh and Robert M. Zingg. Harper and Brothers, New York.* $4.00. 8½ x 5½; xli + 379; 1942.

So much has been written in the popular press about human children reared by wild animals, but so little has been definitely authenticated that the exact status of these stories is still on the borderline between myth and truth. The first part of this book is a diary of the wolf-children of Midnapore, India, who were found by the Reverend Singh. Their day by day activities, their development physically and mentally is narrated in simple style. Unfortunately the kindly missionary was no scientist and hence many important facts have been left out and many observations loosely made. In that respect the diary leaves much to be desired.

The editor, R. M. Zingg, has gone to much trouble to convince the reader of the authenticity of this diary which bears the stamp of approval of several noted scientific persons. The tale itself is an absorbing study of the effects wrought on the children by their feral environment. Even though the children associated with human individuals for several years, they were very slow to regain any human trait; in fact, Kamala was only beginning to walk upright and to speak a few words when death caught up with her after nine years.

The second part of the book, by Zingg, is a review of the literature and known facts concerning other cases of feral man and extreme isolation, especially the celebrated case of Kaspar Hauser. A thoroughly entertaining book deserving careful study.

THE RELATION OF CERTAIN ANOMALIES OF VISION AND LATERAL DOMINANCE TO READING DISABILITY. *Monographs of the Society for Research in Child Development, Volume VII, No. 2. Serial No. 32.*

By Philip W. Johnston. Society for Research in Child Development, National Research Council, Washington, D. C. $1.50. 9 x 6; 147; 1942 (paper).

This technical report on visual anomalies relative to reading ability offers data on many of the eye tests now in use. The reliability of these tests, their methods of application, and the interpretation and significance of the results as given in numerous tables and statistical analyses, make up the major part of this report. The monograph will be of value only to the trained specialist.

DE OMNIBUS REBUS ET QUIBUSDEM ALIIS

THE EARLY HISTORY OF SCIENCE AND LEARNING IN AMERICA. *With Especial Reference to the Work of the American Philosophical Society During the Eighteenth and Nineteenth Centuries. Proceedings of the American Philosophical Society Held at Philadelphia for Promoting Useful Knowledge. Volume 86, No. 1.*

By Various Authors. American Philosophical Society, Philadelphia. $1.25. 10¾ x 8; 204; 1942 (paper).

EARLY NATURALISTS IN THE FAR WEST. *Occasional Papers of the California Academy of Sciences, Number XX.*

By Roland H. Alden and John D. Ifft. California Academy of Sciences, San Francisco. $1.00. 10 x 7; 59; 1943 (paper).

The History of Science is a legitimate field of investigation in its own right, and the biographies of those who have made history constitute perhaps the most fascinating chapter in this story.

Historians generally agree to date the beginning of modern science with the publication of the Copernican theory just four centuries ago this year. But European civilization was already ancient when Copernicus gave his masterpiece to the world from his death bed, and those upon whom his mantle fell had to fight their way against the accumulated beliefs and prejudices of the ages.

Except on the shores of the North Atlantic Ocean the earliest scientists were never more than temporary residents. They associated with the settlers but were not of them. Humboldt and Bonpland, Wallace and Bates, Burton and Speke, Peron and Lesueur (and perhaps Edmond Halley should be included among these) never identified themselves with the tillers of the soil but always looked forward to an eventual return to the fatherland where they might analyze their material and observations and draw conclusions from them at their convenience. The same thing was true of the Pacific Northwest; Steller, Solander, Collignon, and Longinos came, collected, observed, and departed, leaving no influence upon the incipient civilization that was even then struggling to be born. The only exceptions that come readily to mind are Miguel Venegas, Thaddeus Haenke, and David Livingstone, each in a different continent.

On the Atlantic Seaboard a very different situation obtained. While the itinerant naturalists Mark Catesby and Peter Kalm were making their ephemeral peregrinations throughout the Appalachian piedmont there arose a group of indigenous personalities in whom the scientist and the pioneer were aptly blended. Only in the shadow of a slowly advancing frontier could such men have been produced as Franklin and Rittenhouse, John and William Bartram, John Speakman and Thomas Say, Adam Kuhn and Benjamin S. Barton, and here alone were conditions so ripe as to induce such foreigners as Wilson and Maclure from Scotland, Logan and Priestley from England, Michaux and Audubon from France, Troost from Holland, Aller from Germany, and Rafinesque from Constantinople to leave their homes in the old countries and throw in their lots with the pioneers.

As the American Philosophical Society is the oldest scientific institution in the United States it is only appropriate that it should celebrate its bicentennial anniversary by devoting an issue of its proceedings to a recapitulation of the careers of some of these trail blazers of science. By a happy coincidence the oldest scientific institution west of the Mississippi has done the same thing for those who labored on the Pacific Coast.

In both instances there is revealed a tendency for the pioneer naturalist to have begun his career as a physician or surgeon, who engaged in natural history as a recreation but whose achievements in this field eventually eclipsed those in that of medicine. This is true not only of such naturalists as Anderson, Eschscholtz, and Hinds, who accompanied respectively the expeditions led by Cook, Kotzbue, and Belcher but also of Cadwalader Cobden and Alexander Garden, resident physicians of Philadelphia and Charleston. Apart from this resemblance the two groups had little in common, except that there was one man who played a part in the scientific development of both coasts—Thomas Nuttall, the Englishman, who was by turns botanist, ornithologist, and malacologist, and who not only held positions on the staffs of the Academy of Natural Sciences and Harvard University, but also explored the head waters of the Missouri river within a decade of Lewis and Clark, traversed the Oregon trail seven years before Jim Bridger, tramped the beaches of California beneath the flags of the Russian empire and the Mexican republic, rounded the Horn

in a windjammer over a century ago, and then as an anticlimax retired to lead the sedate life of a country gentleman in England.

It is surprising that Nuttall's biographies in these two publications are strangely inconsistent. One writer locates him in Philadelphia during the Napoleonic war; the other has him in London at this time. One states that after his return to England in 1841 he never again left the British Isles; the other states that it was only a short time until he was back in America again.

There are some other peculiar errors in both works, such as the statement that Sessé y Lacosta accompanied the Malaspina expedition. It is true that both parties were in Mexico in 1791 but Sessé arrived a year earlier and there is no evidence that they ever joined forces. Also the statement that David Rittenhouse had been employed by William Penn to run the boundary between his holdings and those of Lord Baltimore is erroneous. Penn had been dead for fourteen years when Rittenhouse was born, and if Rittenhouse (who was probably the greatest scientific genius the Western world has yet produced) surveyed any part of the boundary at a later date, no mention of this is made in the field notes of Mason and Dixon, or of Colonel Graham, or in the narrative of Mathews which has been accepted by both Pennsylvania and Maryland as authoritative. What Rittenhouse did was to accomplish a much more difficult task. He surveyed the boundary between Pennsylvania and Virginia, at the same time engaging by correspondence in a diplomatic debate with James Madison in which he persuaded the Virginian to yield every point at issue.

The omission of the name of José Longinos Martínez is unfortunate, for he was the first naturalist to enter Alta California overland, and the first to traverse the length of the state. His predecessors had all accompanied naval expeditions who put in at Monterey and their collecting was confined to the immediate vicinity of that port.

Finally, if Thomas Sully really painted the portrait of James Logan attributed to him he was guilty of an anachronism, for Logan died in 1751 and Sully was born in 1783.

As these pages are perused we meet many of the romantic personages of history, such as Adelbert von Chamisso, who wrote the story of Peter Schlemihl who sold his shadow to the devil; John K. Townsend, artist and ornithologist who did much of the work for which Audubon got the credit; Francisco Hernandez, the court physician of Philip the Second who botanized in America half a century before the Pilgrims arrived at Plymouth; James Logan, private amanuensis of William Penn, an astronomer and mathematician of no mean ability, and a personal correspondent of both Newton and Halley; David Zeisberger, the Pennsylvania German apostle to the Indians and our first anthropologist; and Titian Peale, whose father Charles Willson Peale was a prominent portrait painter and the first American to excavate and exhibit a mastodon.

It is a pity that neither of these works has an index, for both are crowded with interesting and important items of information which are hard to find the second time.

PROCEEDINGS OF THE EIGHTH AMERICAN SCIENTIFIC CONGRESS HELD IN WASHINGTON MAY 10–18, 1940 *under the Auspices of the Government of the United States of America. Volume I: Organization, Activities, Resolutions, and Delegations. Volume III: Biological Sciences. Volume VI: Public Health and Medicine. Volume VIII: Statistics.*

Department of State, Washington, D. C. 9½ x 7; Vol. I: 539; Vol. III: 530; Vol. VI: 496; Vol. VIII: 365; 1943 (paper).

In 1896, when plans were being made for the Silver-Jubilee of the Argentine Scientific Society to be held in Buenos Aires in 1898, invitations were issued for the convening of a Congress of Latin-American scientists. This meeting, held April 10, 1898, became known as the "First Latin-American Scientific Congress." It was followed in 1901 by the Second Latin-American Scientific Congress held in Montevideo, and in 1905 by the Third Congress at Rio de Janeiro. As in previous meetings there were individual sections, each devoted to a special science: public and private law, ethnology, archeology, linguistics, medicine and sanitation, and other subjects. It was at the close of this meeting that a resolution was adopted to hold the Fourth Latin-American Scientific Congress at Santiago de Chile in 1908 and to restrict the agenda "in so far as possible to matters of a distinctly inter-American nature." It was also voted to extend an invitation to the United States of America to take part in the conference. The Fourth Latin-American Congress, held in Santiago, December 25, 1908 to January 5, 1909, thus also became the First Pan American Scientific Congress. "... the official delegates of the various countries were the ranking scientists in the service of their respective governments. Furthermore, the majority of the great institutions of learning in America evidenced their full accord with the objectives of the Congress by sending leading members of their faculties as delegates." The fifth in the series (Second Pan American Scientific Congress) convened in Washington on December 27, 1915; the sixth in the series (Third Pan American Scientific Congress), at Lima, Perú, on December 20, 1924. As was the case at all previous sessions many delegates attended the meetings. It was at this time that the decision was reached that the next meeting should be known as the "Seventh American Scientific Congress." The economic crisis of the late Twenties and early Thirties resulted in two postponements of the Seventh Congress and when the

meeting was finally held it was in Mexico City, from September 8 to 17, 1935.

Once again, as in all the previous assemblies, there was evidenced the threefold value of scientific collaboration on an inter-American scale: the fraternity of nations, the advancement of science through the opening of various national sources to scientists of other nations, and in a particular sense, the benefit derived from the personal discussion of those conclusions which, after painstaking research, the scientists of all the American nations had submitted to the Congress.

The Eighth American Scientific Congress was held in Washington in 1940. The various sectional meetings were as follows: anthropology, biology, geology, agriculture and conservation, public health and medicine, physical and chemical sciences, statistics, history and geography, international law, public law and jurisprudence, economics and sociology, and education. The volumes of the proceedings of the various sections have been appearing within the past year or so. These are not for sale but there is a limited distribution by the Department of State to participating individuals and organizations and to certain depository libraries and institutions.

Volume I of the *Proceedings* is concerned with introductory matter, organization, rules and regulations, addresses of The President of the United States, as well as of other officials, and responses of the various representatives of the American countries and delegates, minutes of the various section meetings, and resolutions and recommendations. The latter half of the volume is taken up with a list of official delegates and members of the Congress, giving titles and committee membership.

In Volume III are reported the papers, either in full or in abstract form, given in the division of the biological sciences. They are grouped under the headings of General biology (25 papers), Botany (27 papers), and Zoology (29 papers). In the volume on Public Health and Medicine (Volume VI) the grouping of the papers is as follows: Health education and sanitation (13 papers), Nutrition and dentistry (21 papers), Heart and blood diseases (17 papers), Communicable diseases (6 papers), Leprosy (6 papers), Bartonellosis (4 papers), Brucellosis (4 papers), Chagas' disease (3 papers), Tuberculosis (15 papers), Plague (3 papers), Yellow fever (4 papers), Malaria (7 papers), Rickettsiasis (5 papers), Miscellaneous communicable diseases (12 papers), Cancer (6 papers), Maternology and Peuriculture (4 papers), Psychiatry (4 papers), Miscellaneous (17 papers). In Volume VIII, dealing with subjects from a statistical point of view, there was no division of the papers into special groups. Many of the 50 papers presented were concerned with population problems.

All of the papers are important in their special fields and many of them are of considerable general interest. While many are in English a goodly number are in Spanish and Portuguese. Perhaps one of the important lessons to be learned from these volumes is the growing need for a better understanding of the languages of the South American countries on the part of North American scientific workers. That the Congress has become a firmly established institution is evident by the large attendance at its meetings and the interesting reports of the delegates. An understanding of the problems presented and the interchange of ideas can be immeasurably advanced by a wider knowledge of the languages of those attending the meetings.

A HISTORY OF SCIENCE *and Its Relations with Philosophy and Religion. Third Edition, Revised and Enlarged. By Sir William Cecil Dampier (Formerly Whetham). Cambridge: at the University Press.* $2.95. 9¾ x 6¼; xxiii + 574; 1942.

In this readable book the author has attempted to trace the history of science from the time of the Greeks to the present day—its origin, its development and its achievements—and to relate it to philosophy and religion.

The author states in the preface that "Men of science, most of whom used naively to assume that they were dealing with ultimate reality, are coming to see more clearly the true nature of their work. . . . The approach to reality, through science, therefore, gives only aspects of reality, pictures drawn on simplified lines, but not reality itself." It is this idea that the author impresses on the mind of the reader as he reveals the fascinating story of science from its earliest beginnings down through the most recent developments in the fields of physics, biology and anthropology—i.e. he treats "of the growth of those activities which have revealed the individual atom and opened to our vision the depths of space, which have revolutionized philosophic thought and given us the means of advancing our material welfare to a level beyond the dreams of former ages."

As is often the case with such works, this book is a history of science with the emphasis not on science, but on its philosophical implications. In such a book there are many features which are hard to reconcile with sound scientific practice. There is a general tendency to concentrate on the more startling and spectacular advances without an adequate consideration of many intervening discoveries which may have been even more important from the standpoint of actual scientific application. There is also an overwhelming tendency for the author to "go beyond his data" in discussing the significance of scientific advances. It is true that he does this with reservations, but it is questionable whether anything is gained by discussing, in the light of present scientific knowledge, such things as free-will and determinism or whether science is capable of reaching ultimate reality. The scientific

facts are simply inadequate for a scientific discussion of such subjects.

This third edition has been expanded to include experiments and discoveries of the past few years and contains a new chapter covering the years 1930–1940. The text is amply footnoted and provided with marginal headings.

The book may appeal to those with a primarily philosophical interest or to laymen desiring a general historical knowledge of the subject without details, although both may be somewhat disturbed by the advanced mathematical formulations which are stuck here and there in the text with little effort to prepare the reader to understand them. It is hard to see what value these will have for the average reader unless they represent a test of faith, something for the reader to believe, but beyond his ability to solve or understand. For the active scientific worker the book will seem to be somewhat misdirected.

THE METHODOLOGY OF PIERRE DUHEM.

By Armand Lowinger. Columbia University Press, New York. $2.25. 8¾ x 5½; 184; 1941.

The present treatise has been prepared with the hope that it "will stimulate further English exposition of Duhem's ideas, especially his physics and history of science, which are of at least equal importance with his methodology." Pierre Duhem (1861–1916), after receiving his doctorate in the sciences, taught at Lille, Rennes, and finally at Bordeaux, where for many years, until his death, he was Professor of Theoretical Physics on the Faculty of Sciences. One paramount idea dominated his thinking throughout his life but in expanding this idea he proceeded in various directions. He proposed as his objective to work at the creation of a science which would unite the principles of Mechanics with those of Thermodynamics. This science, which one could call general *Thermodynamics* or *Energetics*, would unite under common laws: the study of local movements by bodies of Mechanics properly so-called, that of their physical or chemical changes of state, or physical Mechanics, finally that of electric phenomena and magnetism.

Previous to Duhem, thermodynamics was confined to statics. The idea of thermodynamics of bodies in movement, Duhem's most important contribution to science, came to him while he was at the College Stanislas, before he had finished his education at the Ecole Normale. Both Willard Gibbs and Helmholtz influenced his thinking at this stage of his career.

Duhem's researches led him into the study of scientific method in general and to the exploration of historical fields of scientific doctrines. He made outstanding contributions in both these fields. He traced some of the leading principles of modern science back into the Middle Ages. He found the work of Jordanus Nemorarius in the thirteenth century forshadowing the principle of virtual displacement. In the dynamics of the "Parisians" of the fourteenth century "he finds fully and clearly developed modern dynamics as formulated by Galileo. Buridan destroys Aristotelian dynamics, which required the continuous action of a motor power in order to sustain motion, by his concept of an impetus."

Lowinger's contribution to an understanding of Pierre Duhem is a thoroughly scholarly work. The volume is completely documented, a bibliography is provided, and the index, carefully prepared, will be found useful. The volume will not only interest the physicist but the reader of general science.

SCIENCE IN PROGRESS. *Third Series.*

By Harlow Shapley, Edwin Hubble, Hans A. Bethe, V. K. Zworykin, P. W. Bridgeman, Lionel S. Marks, James Franck, John G. Kirkwood, Perrin H. Long, and Hermann Mark. Edited by George A. Baitsell. Yale University Press, New Haven. $3.00. 9¼ x 6; xiv + 322; 1942.

The past few decades have seen the various fields of scientific endeavor become more and more specialized and, with this development, it has become increasingly difficult for workers in one field to keep up with or even understand current advances in other fields. The National Sigma Xi Lectureships have done much to bridge this gap and the publication of these lectures in book form makes them accessible to many who were not able to hear the original lectures. Each chapter represents a lecture by a man chosen as an outstanding representative of his particular field of research. They are designed for a scientifically trained, but unspecialized audience and usually represent an admirable balance between simplicity and precision of presentation. They thus avoid the many inaccuracies and fallacies which always seem to creep in when a writer or speaker attempts to "popularize" science, and yet they avoid many of the complicating details found in the journal literature on any one of these subjects. The chapters vary considerably in regard to the details involved, but all are clearly presented. It is quite possible that many biologists will not be able to follow all of the mathematical manipulations involved in Zworykin's discussion of the electron microscope, but the general discussion of the topic which is also presented will do much to smooth over the mathematical difficulties for most readers.

The present volume contains the following lectures: Galaxies, Harlow Shapley; The problem of the expanding universe, Edwin Hubble; Energy production in stars, Hans A. Bethe; Image formation by electrons, V. K. Zworykin; Recent work in the field of high presures, P. W. Bridgman; Recent developments in power generation, Lionel S. Marks; Some fundamental aspects of photosynthesis, James Franck; The structure of liquids, John G. Kirkwood; The mode of action of

sulfanilamide, Perrin H. Long; and Some scientific aspects of the synthetic rubber problem, by Hermann Mark.

This volume is certainly worthwhile reading for any scientist, and represents a valuable addition to the *Science in Progress* series which has done much to break down the vicious isolation of the various fields of scientific research.

THE AMATEUR SCIENTIST. *Science as a Hobby.*

By W. Stephen Thomas. W. W. Norton and Company, New York. $2.75. 8 x 5⅜; 291; 1942.

The realm of the amateur scientist has too long remained obscure, not only to the laity, but to academic circles as well. Into this revealing little volume, the author has gathered a body of interesting and pertinent facts concerning science as a recreational hobby.

The amateur scientist has been scrutinized from the standpoint of his home surroundings, his occupation, his organizations, and his scientific contributions. By and large, it is agreed that from the use of a few moments of spare time, the application of a little common sense in the direction of the scientific method, and the exercising of a great deal of patient observation, the amateur scientist has made many contributions in the fields of botany, ornithology, meteorology, archaeology, entomology, horticulture, radio and photography. The amateur scientist clearly possesses a considerable advantage over the academic scientist in his scope of interest and activity, since he is not limited solely to those fields of endeavor which promise the greatest financial return, or which are considered of such importance as to be subsidized by our leading philanthropists.

The magnitude in which the present war effort has drawn upon the ingenuity and originality of the amateur scientist for time-, material-, and money-saving devices for the production of a variety of goods, is only a slight indication of the importance of this phase of scientific activity in the society of the future. For every person young or old, who possesses some spark of scientific curiosity, the contents of this volume will prove to be a real tonic.

Appendices A and B carry a distribution by occupation of some 725 amateur scientists, and a series of sample amateur scientific research projects. The volume is provided with an index.

THE PRINCIPLES OF FIELD DRAINAGE.

By H. H. Nicholson. Cambridge: at the University Press. $3.00. 8½ x 5½; xi + 165; 1942.

The author's ten years of practical field experience in the British Isles have served him well in the inception and preparation of this little volume on the problems and methods of field drainage. His interest and enthusiasm for the subject are derived from the common sense viewpoint that the better the theory of a problem is understood, the better it can be handled practically in everyday experience.

Very little study has been devoted to the problems of field drainage in Britain in the past, but with the present war-time need for more agricultural land, as well as for more runways and landing fields for air transportation, the problem of reclaiming swamp land has received timely and well-advised consideration. The importance of drainage is further emphasized by the fact that something between a third and a half of the total available agricultural land of Britain requires some measure of drainage before it can be put to any use whatsoever.

The author has included discussions of soil structure in relation to water, the various methods of drainage best suited to different types of soil, as well as the principles of flood prevention.

The work is illustrated with photographs and charts, and is supplied with an abundance of tabular material. A short bibliography and an index are appended.

CHEMICAL-TECHNICAL DICTIONARY. (*German-English-French-Russian.*)

By A. W. Mayer. Translated under the Direction of B. N. Menshutkin and M. A. Bloch. Chemical Publishing Company, Brooklyn. $8.00. 8½ x 5½; 872; 1942.

This is an important book for chemical and technical laboratories and for research workers as well as translators. The rapid progress of scientific work in Russia up to the time of the war, with the consequent output of scientific literature, brought about a need for the means—for the Russian as well as for the English, French, and German workers—of understanding technical terms as they are used in all four languages. In this comprehensive volume of over 850 pages it would seem as though few terms had been omitted. The words are alphabetized in German. We give, as an example of the method of presentation, the following word:

Fäll-mittel *n* || precipitant; precipitating agent. || précipitant *m.*; agent de précipitation; осаждающее средство реактив./alkalisches-. || alkaline precipitant. || précipitant *m.* alcalin: щеночный осаждающий реактив

THE NATURAL-HISTORY BACKGROUND OF CAMOUFLAGE. *Smithsonian Institution War Background Studies Number Five. Publication 3700.*

By Herbert Friedmann. Smithsonian Institution, Washington. Free. 9⅛ x 6; 17 + 16 plates; 1942 (paper).